SKIN GRAFTING

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Preface to Third Edition

This third edition has been completely revised and much new material has been included The use of pedicle flaps is covered more fully to describe the most acceptable repair for each lesion under discussion

Chapters on trauma resulting from farm industrial and traffic accidents are added and also on the repair of atomic radiation electrical and cathode-ray injuries

The use of postmortem skin homografts summaries of much experimental work on this subject and details of the clinical maintenance of a skin bank are included.

Material has also been added on permanent pedicle blood-carrying flaps repairs of genitalia, further uses of composite grafts and other things

The early excision and grafting of many small and medium-sized deep burns is described together with other efforts to reduce the time and the expense heretofore required for the successful repair of these injuries

To review or to list credit of all articles on plastic surgery effectively would require an additional volume however a bibliography is included

Plastic surgery has had the following tribute paid to it by Dr Michael Mason Plastic surgery has not only grown into adulthood since the early part of this century but has made a real impact on all surgery The past war has seen the triumph of plastic surgery and the growth of a whole group of plastic surgeons serious-minded and earnest in the development of this important field The plastic surgeon, with his meticulous technic, his respect for tissues his insistence on careful hemostasis and respect for blood supply, his demand for fine instruments and suture material and for accurate closures has called the attention of surgeons to the importance of these principles in all surgery Plastic surgery is no longer synonymous with skin-grafting the plastic surgeon has put skin grafting where it belongs as a technic of surgery applicable to all fields of surgery, just as is suturing or hemostasis

The procedures described in this book are those which the authors use and have found to be valuable Dr Minot P Fryer has worked in close association and great credit is due and is extended, for his efforts

James Barrett Brown
Frank McDowell

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1

Introduction

Skin regenerates rapidly and completely when only part of the thickness is lost as in an abrasion a superficial burn or following the removal of a split graft but it does not regenerate at all when it is divided or injured through its entire thickness as in a laceration or a deep burn In such instances the defect is bridged with granulation tissue (which later becomes fibrous scar) covered by a friable sort of epithelium This substitution is fairly satisfactory when the area is not too large or when it is not in a highly specialized place such as an eyelid where *mobility and softness are necessary* In all these instances a more adequate covering can be obtained by grafting

Free skin grafting is a rather recent development which is not yet widely understood or appreciated Although pedicle flaps of subcutaneous tissue and skin were occasionally transferred in ancient times pinch grafts were first described by Reverdin in 1869 and full thickness grafts by George Lawson in 1870 Ollier described in 1872 both full thickness and partial thickness grafts of from 4 to 8 sq cm in area and apparently realized some of the possibilities of covering large areas with partial thickness grafts if a satisfactory method of cutting them could be developed In 1874 Thiersch published a report on a small series of patients on whom he later used these grafts. Following this the idea became widespread that such grafts should be cut extremely thin in order to leave some of the surface epithelium behind to heal the donor site This necessitated the use of little thin chips of graft which became known in the English medical literature as Thiersch grafts ' epidermic grafts" or 'razor grafts and were so generally unsatisfactory for resurfacing that their use was limited to healing small refractory ulcers Skin grafting changed little during the next 50 years which was the golden age of abdominal surgery' and during which most surgeons were occupied in bringing this specialty into full flower

About 30 years ago a revolution occurred in skin grafting as the result of three developments (*1*) *It finally became apparent* that the dermal pad is the most important part of a skin graft in producing a new tough, resilient surface (2) It was demonstrated that the donor-site epithelium, after removal of a partial thickness graft regenerates from deep islands of hair follicle and sebaceous-gland epithelium This meant that *the grafts could be cut as thick as possible* rather than as thin as possible and that useful amounts of this dermal pad could be *transferred without interfering with the* healing of donor sites (3) Since the grafts were to be cut much thicker it was possible to devise instruments (suction retractors and long knives) for cutting really large grafts These thicker grafts were named split grafts " as the process of cutting them seemed similar to the splitting of leather in a harness shop

For the first time large areas could be resurfaced satisfactorily and could be measured in terms of square feet rather than square centimeters. These split grafts, in

sheets, were so superior that pinch grafts practically dropped out of general use Many old rules were abandoned when it was found that contracted axillae and necks could be repaired much better with these grafts than with pedicle flaps Conversely, the use of the split graft for covering donor areas increased the facility of transferring large flaps or free full-thickness grafts Skin grafting became a routine procedure rather than a rare one

The surgeon no longer has to decide whether a wound will finally heal spontaneously without grafting Rather, he has to decide whether a better final surface will be obtained with a graft, or whether the convalescence of the patient can be shortened weeks or months by grafting (Plate 1)

By trial and error, procedures have been developed which practically assure the "take" of a skin graft In many instances, this means close personal attention to details by the surgeon to obtain success Some of these important details are likely to be considered "trivia" by the surgeon who does only occasional skin grafting This sometimes leads to the publication of reports of "new" procedures by which a few grafts have been done with 60 per cent or 70 per cent "take," but it should be realized that something serious has gone wrong whenever a single graft is lost New procedures are being developed, but they should lead to routine success in the "take" of grafts to be worth while

There has been a large volume of work and development in the free grafting of skin in recent years, including methods of wound preparation, early grafting, methods of cutting grafts, the use of postmortem homografts to save life, attempts at prolonging the survival of homografts, and the widening use of skin grafts. Skin grafting has become a widely used technic of surgery applicable to all fields, due to the efforts of plastic surgeons

The repair of defects should be as close to normal as possible, free grafts may be best in some patients, whereas others may require the thicker repair of a flap The two—free grafts and pedicle flaps—should not be confused in reporting or in recording, and especially not in contemplating what is best for an individual patient

The preponderance of skin grafts is done for burns Because of this, and because burns present an unusually good opportunity for the study of wound healing, they will be considered first and in greatest detail

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Burns. General Considerations

The story of the burned patient begins with the minute of his accident and should continue to the day on which he finally resumes his place in society. Evaluation of the final results can serve as a criterion for the trustworthiness of the procedures that have been employed.

In the extensive literature on burns there has been a notable lack of reports of completed cases, i.e., final demonstration of patients who have been badly burned and have not only been treated and saved from death but also have had complete final and satisfactory surgical repair of resultant open wounds and contractures (Figs. 1 to 4). Apparently, most effort has been devoted to the development of some single method of caring for the local area and of taking care of the acute stage of shock. Seemingly the wounds are allowed to heal as they will or the final outcome—functional and cosmetic—is not reported.

Possibly there has been too much preoccupation with temporary supportive therapy of fluids, etc., until some surgeons have even felt that this is treating burns. In many instances, however, this is simply a preliminary maneuver to keep patients alive and get them in condition for the definitive surgical treatment of replacing the lost skin. Although quite necessary, pouring fluids and blood into a patient with extensive raw burns may be likened to pouring them into a sieve, the determination and the maintenance of fluid balance may be difficult or almost impossible. The definitive treatment is to stopper these raw areas with adherent live skin at the earliest possible moment—permanent autografts when feasible, otherwise with temporary homografts until such time as they can be replaced with the patient's own skin. When this is done, the patient's own regulatory mechanisms take over and will keep him in better fluid and electrolyte balance thereafter.

This work has been of great value, however, in calling attention to the serious nature of burns and might be said to have stimulated a "burn consciousness" in many physicians and in many hospital services with the result that the burned patient now generally receives much better care and more interest than heretofore.

One of the main obstacles seems to have been the confusion of superficial and deep burns and the ensuing healing processes in each instance. The term "deep burn" is used here to designate one that has completely destroyed the full thickness of the skin. Where there has been such a loss, surface healing will have to progress from the edges of viable skin, there will be production of deep scar, and, if healing finally occurs, there will be a thin surface covering that may be called "scar epithelium." If the loss is over a large enough area, there will also necessarily be a primary contracture of surrounding tissues that are pulled in by the scar, and, if healing has been long delayed, there will almost always be secondary contractures of underlying muscles, tendons and joints.

This contracture and scar formation will take place in every extensive case regard



Fig 1. Total loss of skin of both thighs and buttocks 26 large homografts from 26 donors were used as "emergency dressings" before permanent autografts were done, in this instance this procedure was thought to be lifesaving Homografts persisted from 3 to 10 weeks The black-appearing area is a granulating surface, not a tannic-acid membrane (Ann Surg 115 659)

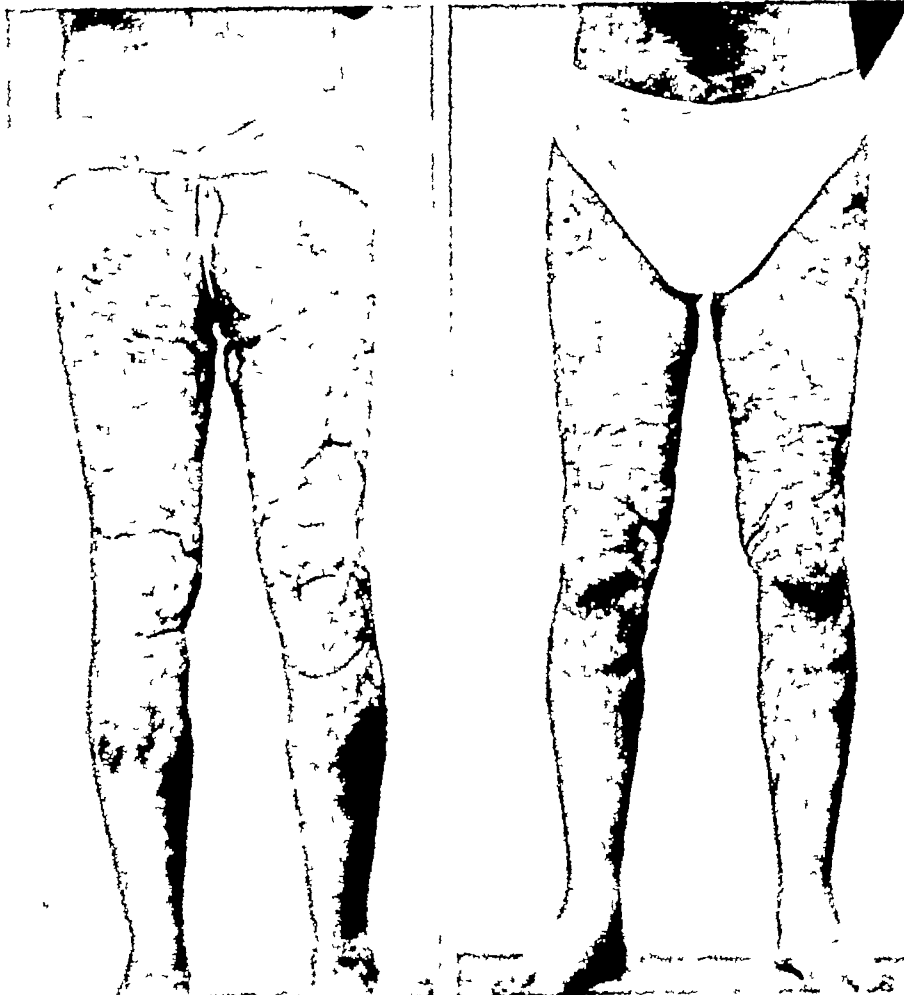


Fig 2 Total restoration of function in 5 operations (same patient as Fig 1) 600 square inches of skin taken from the back and the abdomen, 4 "crops" from the same areas, and 1 "crop" 19 days after the preceding one Scars on donor sites are hardly [illegible] able The pa[illegible] resumed wor[illegible]

PLATE 1



(*Top*) Front view and (*center*) back view of extensive full thickness burn in a child, repaired in two split-grafting operations with result shown in bottom picture Total hospitalization was 80 days and homografting not required in this case.

of the type of treatment used if early s are not taken for the replacement of surface tissue, in fact, permanent healnever may occur if the area of fullkness skin loss is excessive Late deaths n these huge debilitating wounds have been uncommon, and any large deep may present the problem of getting onably early coverage to preserve life g 1)

large series of patients who have reed deep burns have been cared for and hed by us over a long period They have seen in all stages that is, (1) fresh after several days or weeks when open cted wounds have been present, (3) later n healing in a position of deformity has irred, or (4) in a late stage of chronic ecurrent ulceration

n this work it is hoped mainly to outthe essential points of care which have n beneficial in treating this group of pats who have suffered full-thickness loss skin and require skin grafting to give able restoration and function

'he active co-operation of the surgical dents, the interns and the members of nursing staff has been invaluable, withthis, the work would not have been pose In this connection, it is easier to main- such interest if the repairs are done as idly as possible so that the initial period hospitalization is a few weeks or months ier than years The progress should be h that it is definitely measurable from k to week, and it is important to the ient's morale that he realize what has n accomplished, what is to be done and n The treatment must be individualized each patient, but all who come in cont with him should understand that the idance of pain and the cleanliness of inds are the essence of good care.

ome general observations on the care of burned patients will be included, but an mpt will not be made to cite and corre- all the excellent procedures and experintal work recorded in the literature Rather, this is intended to be a summary of the work that has been done and the procedures presently employed on our service.

PREVENTION, INCIDENCE AND MORTALITY OF BURNS

Prevention would be the best treatment for burns, and all physicians have an opportunity to help educate the public about them Burns in children are particularly frequent, serious and pathetic, and their prevention would seem to be especially desirable

The statistical approach to burns, as with other surgical subjects, may lead to gross inaccuracies There are marked variations according to geographic areas, time, habits of the population, size and depth of the burns, age groups of the patients, general and local treatment, etc. In some situations, various sets of these factors may be additive, and in other situations they may tend to cancel each other out A conclusion that may be true on a wide basis may be untrue as applied to a particular situation With these reservations, a few selected statistics will be presented, for whatever value they might have

Some recent nationwide surveys in the United States have indicated that accidents cause more deaths in children aged 0 to 15 years than all other causes combined, and that burns are the second most frequent of these accidents (inhalation of foreign bodies being most common) This, combined with the pain, the suffering, the crippling and the disfigurement which occurs in the large percentage of burned children who do live might indicate that burns are the largest single hazard of childhood

In our own experience certain causes of burns by age groups stand out In infants and very young children there is an appalling number of scalds, from improvised "croup kettles" and from hot coffee In toddlers many serious burns occur from children walking up to the kitchen stove and

pulling down on any protruding pot handle to see what is inside the hot liquid usually lands on their faces necks and axillae with serious consequences to life and to future appearance In school children fire burns predominate—usually from playing with matches or with flammable liquids These are sometimes the result of or made worse by *wearing clothing that is extremely flam mable* In teen-agers and adults fire burns result most commonly from the use of flam mable liquids Many of these are from the use of small quantities of gasoline or kero-sense to start fires others occur around garages or filling stations or from the use of 'dry-cleaning' fluids at home Smoking and dozing accounts for a fair number of serious burns.

Metropolitan Life Insurance Co statistics (for 1950) indicate that the mortality from burns in the United States is at a lower rate than it ever has been In the age group of 1 to 74 the recent death rate has been 1.3 per 100 000 population annually This is about one half the 1936-40 rate and one seventh the 1911 15 rate In the age group of 1 to 9 yrs the rate has dropped 90 per cent in the last 40 years.

They found that in children under the age of 5 years scalds from hot liquids or steam account for two thirds of the fatal burns among boys and one half among girls

In children aged 5 to 14 years stoves and grates accounted for one half of the burn deaths in girls and one fifth among boys In boys of school age flammable liquids out ranked everything causing one quarter of the deaths There was an appreciable num ber of fatal burns in both sexes from play ing with matches

In the age group 15 to 64 years flam mable liquids were the chief source of fatal burns in men and stoves and grates were involved in two fifths of those in women Gasoline explosions in filling stations and garages were common causes, as were paint remover and paint explosion burns, pouring gasoline or kerosene on fires to get them started caused many deaths Flammable dry cleaning fluids caused an appreciable num ber in women Among the stove and grate burns in women, a number occurred in elderly women with poor eyesight. Careless smoking-dozing caused one sixth of the deaths in men

Colebrook (in England) noted that 70 per cent of burns occur in and around the home and 30 per cent in industry Unguarded flames and flammable clothing were chief causes in that area He estimated that the care of burns in England (population 42 million) requires 875 000 hospital bed days each year

Bull and Squire (in England) analyzed the mortality rate in burned cases according to age in 794 hospitalized patients (See bottom of this page)

Fire and heat are such an integral part of our civilization that burns cannot be eliminated but widespread publicity of the following might reduce their number sig nificantly

1 Instruction of parents, and all physi cians who care for children of the hazards of improvised steaming arrangements for respiratory infections

2 Instruction of mothers regarding dan gers of pans containing hot liquids, with handles protruding where young children can reach them

3 Instruction of clothing manufacturers stores and the general public of the danger in using flammable materials for clothing, particularly in fluffy or ruffled dresses for young girls (some of these ignite explo-sively like gunpowder or dried-out ever green trees)

4 Continued and more effective teaching

Age 0 to 14 yrs	51% burn required to kill 50% of patients
Age 15 to 44 yrs.	40% burn required to kill 50% of patients
Age 45 to 64 yrs.	23% burn required to kill 50% of patients
Age over 65 yrs	9% burn required to kill 50% of patients

concerning the dangers of keeping any inflammable liquid in or around homes, and particularly the hazardous practice of starting fires with the aid of kerosene or gasoline

5. More effective and universal guards around stoves and room heaters of all types

6 Wider appreciation of the burn hazards associated with smoking—particularly in bed, or when mixed with alcohol or drowsiness

Burn Wards and Divisions

Although bacteriologic and research reasons are usually given as justification for burn wards or divisions in hospitals, some of them were originated in order to segregate burns away from more "acute cases" or with the feeling that burns are necessarily "chronic cases"

To the extent that this latter feeling or attitude persists the use of burn wards may be undesirable in some instances There are some possible psychological advantages to burned patients, and to their surgeons, nurses and house staff in having them on a general surgical division where the average hospital stay is about 8 or 9 days. This may help impart a certain sense of urgency about the whole thing, which is desirable, and prevent everyone from subconsciously thinking that the hospital is a "second home" for an indefinite period

Although massive burns may require considerable hospitalization, usually they are in the minority, and such burn divisions have a tendency to become filled with small or medium-sized burns, with a further tendency to treat the latter in the same manner.

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Early General Care of Burns

It may be taken for granted that anyone accepting the care of badly burned patients will have his own ideas already at hand for the general care of the patient in combating shock, etc., but, for the sake of completeness we can include an outline of procedures This is desirable also because it may be difficult to differentiate general care from local care of the wounds in some phases of treatment

The literature is replete with methods of early general care based in each instance on the author s conception of the pathogenesis. Data obtained by animal experimentation and by observation of patients, by different workers and various methods, does not always agree, and there is even more disagreement in the interpretations

Much treatment is predicated on various chemical deviations, and these attempts to gain further knowledge are useful and commendable However they do not mean that all of the mechanisms are completely understood or that all deviations are necessarily bad or in need of correction A hypersomething in the blood may need diminution, or may be similar to a hyperleukocytosis in infections a hyposomethingelse in the blood may need increasing or may resemble hypoperistalsis in peritonitis Indeed it has been observed that some therapeutic efforts along these lines have made the charts look better but the patients look worse

It is recommended that all laboratory and bedside observations that are reasonably possible be made and that the treatment be formulated from both of them not one to the exclusion of the other

The early general care of burns will be considered under the divisions of (1) burn shock, (2) the postburn phase, and (3) the important subject of control of sepsis, which will be treated separately

BURN SHOCK

Primary shock is of short duration and is thought to be of nervous origin. It has been attributed to massive stimulation of pain endings or to emotional aura surrounding the accident and has been likened variously to syncope or to a blow over the solar plexus It cannot be readily produced in animals and therefore is not well understood but may be associated with widespread reflex capillary dilatation Few fatalities occur at this time as a rule, the patients have either recovered from this stage or died by the time they are seen by a physician Consequently, the treatment usually recommended is "general and supportive measures' (For first aid treatment, see Chap 4)

Secondary shock is often present or imminent when the severely burned patient is first seen by the physician Very much has been written about this and rightly so [1] but a complete review of the subject will not be attempted here Its duration usually is measured in hours and when present its

[1] Cf Womack, W A., Editor On Burns Springfield (Ill.) Thomas 1953 Moyer C A Fluid Balance Chicago Year Book Publishers, 1952 and other recent treatises on burn shock and fluid balance

alleviation should supersede all other treatment. Most of the evidence indicates that it is due to a diminution in the blood volume and flow, secondary to massive leakage of a plasmalike fluid through the capillary walls out into the interstitial spaces Most of the leakage seems to be in the region of the burn, but some evidence indicates that a similar though less extensive process occurs throughout the entire body Some fluid, of course, is lost through the wounds this loss being slow but of long duration so that it may be more important in producing late debilitation than early shock Many agree that the rate of change of hemoconcentration is a more valuable clinical guide for therapeutic measures than the blood pressure, as the latter may not fall until the patient is in a critical condition The increased understanding of this stage and its treatment probably has done more to lower the early mortality during recent years than any other factor.[2]

The treatment of shock is necessarily directed toward maintaining the blood volume preventing any undue increase in the size of the vascular bed and insofar as possible, minimizing leakage from the vascular bed Any desirable adjuncts may be included Several admirable and complete treatises on the subject have been written,[1] but the continuance of research in many centers indicates that our present-day knowledge is by no means final

General supportive measures include the alleviation of pain with small doses of morphine, temporary elevation of the foot of the bed when necessary, and covering the patient to prevent chilling

Prevention of leakage of plasma and subsequent edema of the burned areas is almost impossible, but they may be diminished by early application of pressure dressings This plan has been followed for many years on this service and it is thought that minimizing edema not only conserves the body fluids but also reduces the local susceptibility to infection

Tannic-acid and open-air eschars may constrict and produce this pressure in circular burns but in an inelastic and unyielding manner so that they may go so far as to produce necrosis of the distal parts of extremities This warning should also be applied to the use of pressure dressings particularly when the inner layer consists of wet bandage, but the danger seems to be less The pressure should be produced only by an external bandage which is wrapped on outside some elastic or compressible material Closed or sealing eschars probably do more to prevent surface leakage from the wounds than does open surgical drainage

Even less is known about methods for preventing dilatation of the vascular bed Adrenal cortical extracts have been used for this purpose with various observers obtaining different results It is possible that the late complete vascular collapse occasionally seen may be the result of prolonged inadequate blood volume and anoxia and would be prevented best by early and continuous whole blood transfusions and oxygen therapy Blalock showed long ago that the application of too much heat may hasten or bring about generalized vascular dilatation; the use of hypothermia for the prevention of this is the subject of present investigations

Restitution of the blood volume is the most effective of present methods for the treatment of shock, and someone should be delegated to secure a sufficient quantity of whole blood from the start Equal amounts of intravenous saline usually are given intravenously, or Ringer's solution may be substituted if desired.

Glucose solutions in water end up as pure water The amount of water intake by mouth and by vein must be limited to minimal requirements Excessive amounts

[2] Moyer states "Shock can be well treated, water intoxication can be prevented, but for the severely [illegible] individual, we have accomplished nothing from a mortality statistical standpoint. They live [illegible] only to die of causes other than shock."

may aggravate localized or generalized edema and may even lead to water intoxi cation

Plasma most nearly resembles the fluid lost in burns and it might seem to be the almost ideal substance for replacement ther apy However it has been demonstrated repeatedly that there is a simultaneous mas-sive destruction of red cells and experience has shown that whole blood therapy is better most of the time If pooled plasma is used it should be aged 6 months at room temperature or other measures employed to prevent the transmission of infectious hepa titis Serum albumin can be given on occa sion especially when the patient s hema tocrit reading is excessively high

Many of the recently published facts concerning reduction of the colloidal and electrolytic osmotic pressure in the blood hypoproteinemia the Donnan equilibrium cellular concentration, etc. are old knowl edge and their consideration has formed a part in the everyday treatment of burns for a number of years Tappeiner (1881) Hock (1893), Wilms (1901) and others recognized the importance of plasma transudation in burns and Stockis (1903) summarized the process excellently in one terse paragraph (cf Harkins The Treatment of Burns)

Plasma substitutes are still the subject of much investigation Gum acacia was used during World War I for the treatment of shock and intermittently for about 20 years afterward This is a large molecule poly saccharide and the theory was that the molecules would be too large to leave the circulation and that their colloidal osmotic pressure would hold fluid in the vascular system. In practice it would relieve the symptoms of shock for an hour or two but patients nearly always required whole blood later for permanent relief It was also found that continued use of it produced liver dam age and clogged the reticuloendothelial system.

The Germans used polyvinyl pyrrolidone ("P V P) during World War II for this same purpose Various gelatins and globins have been used in the United States and *dextran* (a large molecule polysaccharide) was introduced in Britain and in Sweden Experimentation is proceeding with these various substitutes in many centers but none has found universal adoption In the early days of dextran difficulty was encoun tered in the tremendous variation in size of the component molecules, but it is thought that this has been corrected There were also some difficulties with allergic reactions to it which appeared to be peculiar to some preparations and not to others At present dextran probably is used more in the United States than the others However it is em ployed mainly as a temporary substitute when blood is not available (in burns) and it is realized that it will not substitute for the loss of circulating red cells and the ability to carry oxygen

The whole subject of plasma substitutes is creating great interest because of the problem of stockpiling for atomic or other disasters but it is not settled at this time

Whole blood transfusions are the best for treating burn shock in most patients The initial rise in the red-cell count is only an index of hemoconcentration and may dis-guise the progressive massive destruction of red cells which probably begins immedi ately and becomes apparent when the blood is diluted to its normal volume Cases have been noted in which plasma transfusions were given early when the red count was around 6 or 6½ million and the cells from this blood were preserved in a saline sus-pension in the icebox. On the 2nd or 3rd day when the red count has fallen to around 3 or 3½ million the cell suspension was given intravenously with resultant improve ment in the anemia. The erythrocyte frac tion of whole blood transfusions may per sist in the blood stream and transport oxygen for periods up to 1 month accord ing to Dr Carl Moore It is probable that it would have been better to have given these patients whole blood initially, and

they may represent fairly typical cases rather than exceptions

A donor's blood with a red count of from 4½ to 5 million does not increase the erythroconcentration when given to a patient with a count of from 6½ to 7 million but dilutes it, and a drop in the count is commonly observed after whole-blood transfusions, although this drop is not so marked as when plasma is used It is possible that in a patient with a severely contracted blood volume and erythroconcentration, the number of oxygen-laden red cells passing a given point during any time interval is actually decreased, and reports concerning anoxia in burns seemed to be more frequent when the practice of discarding red cells was common It is evident, however, that the red count should not be allowed to rise to such a point that the increase in viscosity presents any impediment to circulation

The increase in both the number and the quality of blood banks has done much to make whole blood readily available

Various excellent formulae for determining the amounts to be given have been described by Black, Elkinton, Wolff and Lee, Harkins, Evans and others The more common error, perhaps, is to give too little too late The Evans formula is quoted most often and consists of 1 cc of blood plus 1 cc. of electrolyte solution per Kg body weight for each per cent of body surface burned (plus normal water requirement—e g , approximately 2 000 cc daily for an adult) The above is given during the first 24 hrs , and about half of the above is given the second 24 hrs , and again the third 24 hrs , if necessary The electrolyte solution may be physiologic saline, or half of it can be lactate Ringer's solution Thus for a 75 Kg adult with 25 per cent of body surface burned, one could give 1 860 cc blood plus 930 cc physiologic saline plus 930 cc lactate Ringer's solution plus 2,000 cc water by mouth (or 2,000 cc. glucose in water intravenously) during the first 24 hrs Such formulae may be somewhat useful as a rule-of-thumb check, but they assume that all burns are the same and that all patient s react the same to them, which leads to absurdities if one insists on applying them exactly

On our service, it is routine with a severely burned patient to start a whole-blood transfusion immediately and to keep it running at the correct speed for as long as is necessary An equal quantity of electrolyte solution is given simultaneously or interspersed between the blood transfusions To determine the correct speed, a graphic chart is set up at the patient's bedside, with pulse and blood pressure recordings every 15 minutes and hemoglobin recordings (photoelectric) every 30 minutes The urinary output (per catheter) is recorded as it occurs, and each new unit of fluid or blood is marked down when it is started Every effort is made to keep the pulse and the hemoglobin down to 100 (15 4 Gm %) and the blood pressure up to 100 If the hemoglobin level is rising in spite of the transfusion, an additional unit is started in another vein, or it is pumped in faster with a 3-way syringe until the level is stable In addition to the laboratory determinations, frequent observations are made of the patient's general appearance, and especially his degree of mental alertness and clarity. For this reason, large doses of sedatives are undesirable, though reasonable amounts of morphine may be used

During the first few hours it may be necessary to run the blood in rather fast, and one should not hesitate to do this Nothing seems more futile than a slow dripping transfusion in a patient in profound shock After this the level usually stabilizes so that it can be maintained by a moderate drip and even in widespread burns it is usually possible to cut down the rate to a slow drip in from 12 to 20 hours and discontinue it altogether after from 20 to 24 hours. In deciding when to discontinue the transfusion, one waits until the levels are nearly normal and have been slowly improving

over a 3 or 4-hour period during treatment with a very slowly dripping transfusion After discontinuing it further recordings are made every hour for a little while, and then every 4 hours for another day restarting the transfusion if necessary Plasma electrolyte CO_2 and protein determinations are obtained as often as practical for checks during this early period

The method described above may seem to be rather crude when compared with the various elaborate mathematical formulae but it seems to be easier and more practical than trying to determine precisely a patient s future protein and hemoglobin needs when he is first seen.

In order to carry this out it is usually necessary to have special nurses and to detail a responsible surgical house officer to the early care of the patient in order to follow his progress constantly and see that the laboratory and blood bank details are being carried out properly A really alert house officer can often estimate the laboratory findings with some accuracy in advance by his observations of the patient. Euphoria usually denotes a mild degree of shock disorientation more and progressive degrees of stupor and unconsciousness appear as it becomes critically severe Several hours after treatment is started (usually from 12 to 20 hours in the widely burned patient) fluid transudation out of the vessels into the interstitial spaces stops and then slowly reverses. This is often marked clinically by a sudden large output of urine as well as by a rapid fall in the hemoglobin and stabilization of the blood pressure and the pulse at satisfactory levels At times the change in the facies general appearance and mental alertness in the patient is as dramatic as it is in the crisis of lobar pneumonia

The question of citrate intoxication always comes up in these multiple transfusions Some of our patients have received enough citrated blood within 24 hours to replace their entire calculated blood volume (one thirteenth of body weight) without any apparent intoxication but it seems advisable to use heparinized blood or plasma for the later transfusions when it is obtainable or to cover the citrate with intravenous calcium.

The care and the pampering of superficial veins is of practical importance in these patients with widespread serious burns Such patients will require a large number of intravenous infusions and transfusions during the coming days and weeks and available veins are lifelines In general venipunctures should be done only by those who are skilled in this art, and each one should be used maximally—for intravenous anesthesia blood withdrawals infusions transfusions and everything that is planned for that patient for the next 12 hours or so Firm fixation of the needle splinting of the extremity and firm pressure over the vein after withdrawal of the needle will help to preserve the vein for future use It is also helpful to begin with the most distal veins gradually working proximalward as repeated punctures are done The use of indwelling venous catheters for long periods is not always a good solution as their use may be followed by extensive thromboses or thrombophlebitis This latter complication is not an uncommon cause of fever and other later troubles

The oral administration of fluids electrolytes and protein is obviously important and it is often surprising how much some of these patients will take particularly during the early hours This may explain why some severely burned patients have survived who have been treated at home in rural areas without any parenteral fluids

The use of salt by mouth probably extends back into antiquity (intravenous saline in burns goes back at least as far as 1901 to Parascandolo in Naples and Weidenfeld in Vienna) Favored methods of 20 years ago and still useful include giving the patients pretzels potato chips popcorn peanuts, and other heavily salted foods with

their drink. Drinking solutions of weak sodium chloride and sodium bicarbonate have been used for a number of years in varying strengths and manners Possibly Haldane s solution and Moyer's solution are two of the best-known ones. The latter one is very satisfactory and consists of 1 teaspoonful (4 cc) of table salt (sodium chloride) plus from ½ to 1 teaspoonful of baking soda (sodium bicarbonate) to 1 quart (or liter) of water. It is most palatable when iced, and sometimes the addition of a small amount of citric acid or lemon juice helps

Water intoxication may occur early in severely burned patients as a result of lowered plasma electrolyte concentration unrestricted drinking of water or nonelectrolyte solutions (or intravenous glucose in water), plus diminished urinary output This has been rightly emphasized by Moyer and others Symptoms include those due to edema of the gastro-intestinal tract (ileus and vomiting), edema of the brain (headache papilledema, vomiting, apprehension, and later dulling of sensorium, coma and convulsions), and generalized edema (loss of fingerprints visible swelling, pitting of dependent areas) Prevention includes administration of electrolytes by vein and by mouth, and restriction of nonelectrolyte fluids by vein (e g , glucose in water) and by mouth

Vomiting is a complicating factor in these patients and may be due to morphine, such a patient to open the tent frequently and attend to his wants and needs There is a regrettable tendency to starve patients in oxygen tents and to make them feel that they are isolated, incommunicado and forgotten.

Adrenal cortical hormones have been used in much experimental work in burns, beginning with the nonpotent crude cortical extracts and later using the more potent DOCA and ACTH-cortisone combinations It is easy to prove that marked "alarm reactions" occur in severe burns However, the bulk of the evidence indicates that on the whole, potent cortical hormones do more harm than good in severe burns

Anuria or oliguria is a serious development in a burned patient In the early phases it is due most often to shock or low electrolyte concentrations, and treatment is directed to these causes There may also be some clogging of the kidneys from free hemoglobin, and this is more difficult to relieve; administration of lactate solutions to alkalinize the urine has been recommended

Immediate or early surgery on widespread, serious burns can be fatal, or nearly so This should be postponed until the shock situation is well mastered

Burn shock must be brought under control early if the patient is to survive, and its treatment takes precedence over everything else at this time However, this is not treatment of burns, but treatment of shock

Both the patient and the surgeon should regard this as a phase rather than a chronic state, and do everything possible to shorten or eliminate it This is the period charac terized by pain and debilitation when the patient s life fluids are oozing out of him and everyone is hoping that he will get better Patients who have been carried bril liantly through the shock stage may grad ually deteriorate and die in this phase

This period is also characterized by in ternal chemical shifts and metabolic de rangements and by therapeutic efforts which result in overreplacement of some elements underreplacement of others and no knowl edge at all of still others. Still further shifts and derangements may occur and compound the original confusion These situations are trying to the best of surgeons and require maximum knowledge continuous effort and at least a modicum of good fortune The surgeon should realize that these efforts are not treating burns" but are directed toward keeping the patient alive and getting him in condition for definitive treatment of his burns

At best he is putting fluids food blood etc. into a sieve which is leaking different components at various and unknown rates The problem is further complicated by multidirectional osmotic shifts of various ions between the vascular stream and inter cellular fluid and between the latter and the protoplasm within the cells The only ob- servation window for chemical determina tions is the plasma concentration of a spe cific element as it passes one particular point at one given time It is probable that the available knowledge concerning the import of all of this changing shifting situ ation is infinitesimal compared with that which is not known or understood

The best way out of this predicament is to get the wounds healed—permanently if possible but if not even temporarily As soon as the wounds are healed or nearly so the patient s own internal controls take over and a cure is practically assured

Superficial burns present minimum problems after the initial shock is over If they are kept clean and uninfected, and the patient s general condition is maintained in a reasonably average state, they will heal spontaneously and completely in a short time

Deep burns require removal of the slough and (if of any considerable area) preparation for grafting and getting skin grafts to take, in order to get the wounds healed If less than 15 to 20 per cent of the body surface is involved and the patient is not too old, early excision (3rd or 4th day) of the slough and grafting (on the 5th to the 7th day) can often be done thus almost eliminating this postburn phase (cf Chap 5) In larger burns this may cause too much blood loss and the patient may be in poorer condition, so that the excision of slough may have to be staged or delayed a week or two for some spontaneous loosen ing or separation likewise, grafting may require staging but the sooner the whole procedure is completed the better it will be for the patient and everyone concerned Still larger burns may require staged removal of slough and then temporary coverage with homografts Again, the time should be short these patients tend to deteriorate under even the best care and it is usually advisable to get them in the best condition that can be obtained in a few days and then go ahead with the work

Fluid balance is important to maintain during this period in spite of the difficulties and the vagaries noted above There are several excellent monographs on the sub- ject which will not be abstracted here but with which the surgeon caring for burns should be familiar Ordinarily, plasma Na K Ca Cl CO_2 and NPN determinations are obtained 2 or 3 times weekly or more often if necessary and appropriate therapy is instituted—insofar as it can be deter mined by both laboratory and clinical signs Early in the course of a large burn there is a tendency to diminution of the total elec

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Vomiting is a complicating factor in these patients and may be due to morphine, water-intoxication, or other causes Sustained efforts should be made to prevent it and treat it During the first 24 to 48 hours, patients are permitted, or even encouraged a little, to drink as much weak electrolyte solution as they desire, but fluids are not "forced," and other items of diet probably are not so important during this early period

Oxygen therapy probably is helpful in most patients with large burns, especially during the early shock period However, it should be almost mandatory for someone to be in constant attendance at the bedside of such a patient to open the tent frequently and attend to his wants and needs There is a regrettable tendency to starve patients in oxygen tents and to make them feel that they are isolated, incommunicado and forgotten

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THE POSTBURN PHASE

This period begins when the initial shock is over, it lasts until the patient is healed, or until definitive grafting is undertaken

Both the patient and the surgeon should regard this as a phase rather than a chronic state, and do everything possible to shorten or eliminate it. This is the period characterized by pain and debilitation when the patient's life fluids are oozing out of him and everyone is hoping that he will get better Patients who have been carried brilliantly through the shock stage may gradually deteriorate and die in this phase.

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trolyte concentration of the plasma (water intoxication), and this may recur later Later, there may be a tendency to diminution of sodium (acidosis), or chloride (alkalosis), or both (water intoxication) Potassium deficits may occur in the later stages of burns and may not show a hypokalemia until they become severe Early signs may include scattered twitchings, picking at bedclothes, excessive rambling speech, burning pains, EKG signs, and acidosis refractory to sodium bicarbonate therapy, or alkalosis refractory to sodium chloride therapy Later signs include absent reflexes, muscle weakness and flabbiness, paralyses (sometimes of the Landry's ascending paralysis type), stupor and hypokalemia

Blood transfusions are given frequently to maintain hemoglobin and serum protein levels within a "normal" range It is particularly important to have these levels up just before, during and after skin grafting In general, these are the most effective "tonic" that can be given to burned patients

Diet is obviously important for maintaining nutrition After the first day or two, patients should be encouraged to take a regular diet, if there is no nausea or vomiting Often, this can be advanced quickly to a high-protein, high-caloric diet, with added salt and with additional between-meal feedings If there is nausea or vomiting, the patient should be checked for electrolyte imbalances, or water intoxication with edema and ileus Another cause may be morphine, or other drugs In any event, nothing will be gained from trying to force the feeding of a patient with nausea and ileus, and measures should be taken to try to correct these

Feeding tubes are of value in some patients who have good bowel sounds and movements but are weak, listless, or drowsy, or have anorexia Very small plastic tubes are used, and the feedings may be put in by slow continuous drip, or intermittently The feeding should be constructed so that it has a high protein and caloric content, adequate minerals and vitamins, homogenized sufficiently so that it will not clog the tube and not in itself be productive of nausea, vomiting, or diarrhea Patients can eat by mouth around these tubes and should be encouraged to do so If the patient can and will take enough by mouth, the tube is not needed However, adult patients with large burns require phenomenal amounts of food, it is not uncommon to see one who will require from 7,000 to 8,000 calories per day merely to maintain his weight level

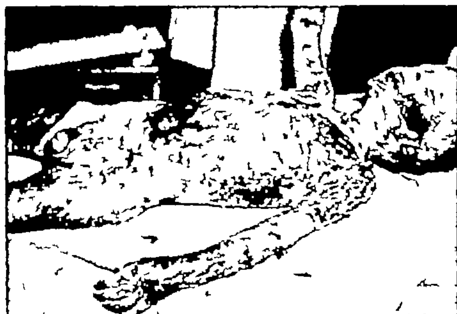
Morale of the patient and those around him is important He should be made to feel that this is a short and temporary phase, that daily progress is being made on a definite program, and that everything possible is being done to get final, satisfactory healing at the earliest possible date Cleanliness of his person, dressings and surroundings is paramount Avoidance of pain, and a pleasant, confident attitude on the part of all who care for him are obviously strong factors in building morale

CONTROL OF SEPSIS

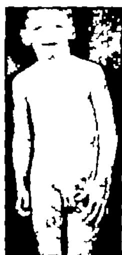
Sepsis is so intimately concerned with the local treatment that it cannot be fully considered here As a general principle, the surface of the wounds should be kept as free of any culture media as possible, and this includes dried serum, blood clots, necrotic tissue and crusts of all descriptions If ointments are used, the old ointment should be entirely removed at each dressing, using ether if necessary Edematous tissues seem to be much more susceptible to infection than others, and keeping down edema by the use of pressure dressings may be of considerable value

These patients should be isolated from any person with an upper respiratory or other infection, and every effort made to prevent additional contamination of the wounds If tubbing is employed, it is necessary to have a separate tub which is not used by anyone else, of course, it must be thoroughly cleansed before each use

PLATE 2







(*Top*) Front view of a child who was moribund when first seen several days after an extensive full thickness burn (*Bottom left*) Appearance after burn slough removed and temporary coverage with postmortem skin homografts. General condition was greatly improved and homografts probably were lifesaving in this instance. (*Bottom right*) Complete healing after homografts were replaced with autografts. Ready for the fourth phase—release of small con tractures and general smoothing up in appearance This patient was cared for by Dr Minot Fryer

Chemotherapy and antibiotics are relied upon to destroy any organisms that have entered the tissues or the blood stream even as local cleanliness and antiseptics are used to keep down growth on the surface of the wound (which feeds bacteria into the tissues and the blood stream) No long term policy in regard to antibiotics may be forecast, as more efficient ones are being developed rapidly, but the ones presently used may be listed

Initial systemic coverage may consist of both penicillin and streptomycin, or tetracycline, or other antibiotic of choice As the use of any particular antibiotic becomes older, more strains of bacteria become resistant to it, and it is necessary to change to another one Even during the course of a particular burned patient, his own organisms may become resistant to one antibiotic after another, with each one being effective for a short time None of the systemic antibiotics seems to have much effect on the "carrion" organisms which grow in surface detritus on the wounds or on the surface of the surrounding skin, constant local cleanliness seems to be the best control measure.

Local antibiotics on the wounds have been rather disappointing Even those reputed to be effective for the "carrion" organisms have not worked out well until the wounds are free of necrotic tissue and detritus once this is accomplished and maintained they are not especially needed

Evidences of infection are ordinarily considered to be foul or profuse discharge from the wounds redness of the surrounding skin margins fever leukocytosis malaise and general signs of "toxicity" The local wound signs are rather positive and may be alleviated by increased cleanliness of the wounds plus changing to other suitable systemic antibiotics in adequate doses The other general signs are not so positive and may be due to pneumonia thrombophlebitis upper respiratory infections pyelonephritis or even to dehydration or various chemical shifts within the body

Cultures and sensitivity tests may be done but have not been so helpful as was once hoped

Burn wards complete isolation, ultraviolet air sterilization etc., have all had their advocates, but all present serious disadvantages The bacterial problem is usually not too difficult to keep under control so that it does not delay healing or grafting

Serum hepatitis is a serious complication but rare when individual blood transfusions are used every known procedure should be used to prevent it, including adequate heat sterilization of needles, etc

Detergents for local cleansing and in first aid applications prove to be of great value especially in badly contaminated and dirty burns It is probable that large wounds cannot be kept sterile by any presently known method but systemic antibiotics may resist invasive tendencies of organisms that may continue to live in large wounds

Bacteriologic studies strict asepsis, occlusive dressings the application of pressure to wounds are all important considerations. It seems that more stress could profitably be placed on the foregoing elements, even though their importance might seem to be too obvious to require such stressing Small essentials such as washing hands between even slight contacts with each patient, masking all attending to open wounds, including the patients, and general ward cleanliness are almost natural procedures for any surgical service but should have frequent attention called to them as fundamentals of success.

In summing up the value of cleanliness in the care of wounds a person might conjecture what he would choose if allowed only one thing The answer would be cleanliness and preserving cleanliness Under this heading could come all the things that improve cleanliness but soap and water or a detergent would come first. This will have much to do with the patient's general comfort and the chances of the quickest possible recovery

PREVENTION OF TETANUS AND GAS GANGRENE

Tetanus and gas gangrene are rather rare in burns but do occur occasionally in deep, necrotic lesions Therefore, the administration of the proper antisera (or toxoid booster) should be considered carefully in each patient

GENERAL CARE OF THE PATIENT

The avoidance of pain, attention to the general physical condition, and applying morale-restoring measures whenever possible are points that should be carried on throughout the course of each patient They are essentials not to be forgotten in enthusiasm for some special subject or procedure Early closure of wounds with grafts before debilitation has progressed is one of the best general measures that can be applied, even though it is a local one

4

Early Local Care of Burns

GENERAL CONSIDERATIONS

In serious burns, any local treatment is delayed until the pain is somewhat relieved with morphine and until any present or impending shock has been treated Meanwhile the burned area is covered with clean sheets with as much added bedclothing over them as seems best for the patient s comfort It is *not necessary* to wait until the hemoglobin, the blood pressure and the pulse have stabilized at a normal level before beginning local treatment but only until transfusion is well under way and a few readings have been taken indicating that the situation can be held at a level where local manipulation will not endanger the patient

There are essentially two methods of treating burns locally (1) *coagulating or tanning or "open-air* which commits one as soon as it is started because it is not a reversible process except with operative removal of the membrane and (2) *surgical drainage methods* which include all of the variations of local care that *can* be reversed By these methods the wound can be exposed and examined and the treatment changed if advisable Even plaster of Paris, paraffin or other occlusive methods in which the dressing or chemical produces a membrane come under this head because they *can* be removed

In this text *surgical drainage"* has been used to denote *reversible* methods and is not intended to mean leaving wounds exposed and unprotected Cleanliness without damaging underlying tissue leaving blisters on hands ears, eyelids using cotton swabs whenever possible using fine mesh gauze (No 44) next to the wound and enclosing the whole area in a surgical waste dressing for pressure to prevent swelling and to produce comfort are basic ideas that still permit surgical drainage and constitute a reversible treatment What ointment or antiseptic to use on the gauze is a variable that will continue as such according to proved efficiency The avoidance of bacterial, chemical and mechanical trauma to the wound remains essential

Plaster of Paris over dressings for joint fixation and for comfort in travel may be helpful but skin does not do well under plaster and any use of it "skin tight" should be done with great caution It is still an open treatment in the sense that it can be reversed

Irrigations and continual baths have been used in deep burns seen late that have come in so infected that this treatment for a period seemed to be preferable to risking the occlusion of a dressing

To a greater extent than in almost any other surgical wound, various chemicals have had their vogues in the treatment of burns and seem to have been applied in the hope that some particular chemical would be found that would be specifically good for burns. During the last 5 years, various authors have published papers on the use of aluminum foil, aluminum powder dibrompropramidine 6 per cent salicylic acid in alcohol, Furacin bacitracin chlorophyll globin alkaline isotonic baths panthenol, phosphoric acid gel, Aureomycin, silicic acid



FIG 5 Primary local treatment of burn (*Top*) Flaming gasoline burn of hand and forearm as first seen about 30 minutes after the accident (*Center*) In operating room after washing with soap and water to remove dirt, grease and necrotic shreds of epithelium (Note removal of ring from finger) (*Bottom*) Application of pressure dressing with fine-mesh grease gauze next to wound, followed by surgical waste, gauze rolls, bandage and adhesive

powder, ammonium salt baths, crushed ice packing, casein gel with zinc acetate, polymyxin, streptodornase and streptokinase trypsin, neomycin, terramycin, benzocaine ointment, gentian violet, various plastic strips and sheets and sprays, bombs, etc — all recommended for local use on burn wounds Some of these may be quite helpful in some situations, of course, but should be used for a specific purpose at a specific time, rather than applied reflexively to every stage and type of injury that is called a burn A burn is a wound produced by thermal, chemical or electrical trauma and, of course, may vary widely in extent and character Its name implies the agent producing it but not the damage sustained or the patient's reactions to it, and it may be more unwise to standardize its treatment than it would be even in all lacerations or all fractures

Conflicting reports of results may have been associated with errors in the diagnosis of the depth of burns and in some instances it is indeed difficult, if not impossible, to estimate this correctly when the patient is first seen The local appearance may be altered by the presence of oils or greases and varies somewhat in scalds and fire burns In general, reddened or blistered areas are apt to be partial-thickness loss, while carbonized areas in some fire burns, or dead-white or dingy gray areas in scalds or fire burns are usually full-thickness loss These latter areas may have diminished sensation in them, while the more superficial ones may be hypersensitive Some patients present widespread redness and blistering with enclosed scattered white patches of full-thickness loss In infants and young children the skin is quite thin, and the worst is to be feared In adults, the thick skin of

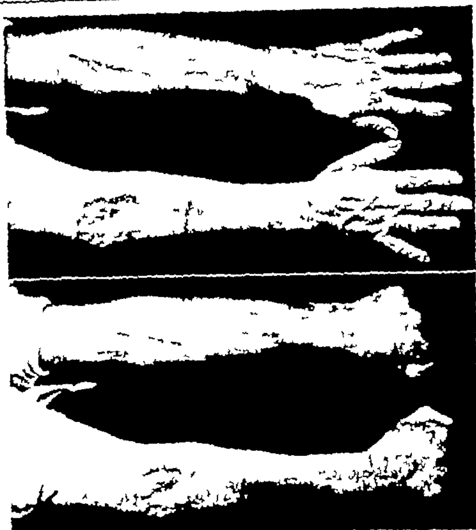


FIG 6 Burn in Figure 5 completely healed 12 days later (redressed twice during that time.) This was a superficial burn but would have been treated in the same manner if it had been deep and would have then been well along in preparation for grafting

the back is only rarely burned through and full thickness burns of the face are apparently sustained more easily in women than in men with deep hair follicles Scalds are apt to be deepest under clothing while fire burns are often worst in exposed regions unless the clothes ignite and burn the skin under them

The relation of body area and depth to possible fatal outcome is uncertain. Huge areas, of course cause more shock initially and present more opportunities for sepsis later, but the relation to mortality is only a gross one. If one is interested in the recording of the percentage of body surface burned the figures of Berkow may be of help For adults—head 6 per cent, arms 18 per cent legs 28 per cent trunk 38 per cent, for children—arms 16 per cent, trunk 40 per cent

It is certain that children and infants stand burns less well than do adults, and, of course there is tremendous variation in individual endurance Roughly, burns of the extremities seem to be borne better than those of the trunk.

FIRST AID TREATMENT

In small, superficial burns the objectives are to allay pain and to avoid doing harm The latter seems to be trite, but patients are apt to use butesin picrate or tannic-acid jellies even in the conjunctival sac when they are included in first-aid kits Immersion of the part in cool water, or cold wet compresses will often give quickest relief of pain Following this initial cleansing can be carried out if advisable, and then any recognized form of treatment used It is well to use some local application that will not per

sist longer than the effects of the burn Fine-mesh gauze with some bland ointment on it can be applied, and there seems to be no particular advantage in the use of any special commercial preparations A firm, secure dressing often gives the most comfort and may be changed every few days as necessary

In either larger or deeper burns, an adequate sedative (about ¼ gr of morphine in adults) should be given and, if possible, and if he is in suitable condition, the patient should be taken immediately to a place where definitive treatment can be started A clean sheet can be wrapped around him to prevent further contamination Treatment of any shock present should be started at the earliest possible moment

Upon arrival at the place where definitive treatment is to be undertaken, measures for general care should take precedence over local treatment, and someone should be delegated at the start to secure blood As soon as the general condition is relatively satisfactory the decision must be made as to the mode of local care

SURGICAL DRAINAGE

This method is generally recognized as the one of choice in burns of the hands, the face and the genitalia, or in other areas if the patient is first seen after 12 hours or after infection or disintegration of a coagulated membrane has begun Many, including ourselves, prefer it in the treatment of all burns

It really is not a single method, but constitutes all of those procedures ordinarily used in the surgical cleansing care of raw surfaces (or surfaces about to become raw) In using it, one tacitly accepts the principle that deep burns are raw surfaces with a necrotic covering, not amenable to any special chemical but treated best by securing rapid separation of the slough and replacement with live tissue

The method involves débridement as soon as feasible, but sometimes in stages, and day-to-day cleansing and dressings with any necessary alterations as the occasions arise Dressings may be either continuously moist, wet to dry, or with ointments, but it is important that some protector be used next to the wounds to prevent any granulations from growing up through the meshes of the gauze and "mushrooming" For this, strips of old linen, perforated cellophanelike material, nylon, rayon, silk, or wide-meshed curtain cloth impregnated with paraffin (so-called "tullegras") can be used However, a very fine mesh (No 44) bandage gauze seems to be most satisfactory and has been used routinely on our service for many years (Fig 35)

Initial Débridement and Cleansing

The initial débridement is done almost immediately if the patient is not in shock, or as soon as his general condition permits The entire areas are cleansed gently but thoroughly with large gauze sponges, mild white soap or some other detergent and water, and ether Blisters are opened, and all loose skin is trimmed away Any evidently charred tissue may be removed, but the dissection should not be carried deep enough to cause bleeding Cleanliness, but not absolute sterility, is involved in the procedure and it is carried out with the realization that any necrotic tissue left serves as a culture medium for the future growth of organisms The washing may be done more efficiently if the operator puts on sterile gloves and uses his hands to best advantage, rather than trying to do everything with long sterile forceps

For large burns, it is usually best to take the patient to the operating room, place him on sterile sheets and anesthetize him with intravenous Pentothal Sodium (the Pentothal needle may be inserted into the transfusion tubing) The work can be divided advantageously among members of the team so that it can be completed in from 15 to 20 minutes Brushes with very soft bristles may be helpful in removing quickly large

amounts of necrotic epithelium from the wounds and any tenacious dirt in them or in surrounding areas Applications of cold cream wiped off with dry gauze and followed by washing with ether can also be used as a solvent for heavy oil and grease Koch Mason Allen and others have re-emphasized the desirability of converting these burns into surgically clean wounds and rightly so

In an occasional very widespread burn one may not be able within the first 2 or 3 hours to get the patient in suitable condition for the procedure described above In these instances, or when so many burned patients are brought in together that there is not sufficient personnel to carry out the procedure it may be necessary to omit the initial débridement, postpone it or compromise with simple washing of the areas in bed However, cleanliness of the wounds is one of the key points of success and should not be compromised except under urgent necessity

OCCLUSIVE PRESSURE DRESSINGS

The initial dressing consists of fine-mesh grease gauze next to the wounds covered by a thin layer of ordinary surgical gauze cotton waste in abundance and large gauze and cotton pads. The whole is wrapped securely with gauze rolls (cf Fig 35 A 4-inch widths being used for the extremities the head and the neck, and 8-inch widths for the body) followed by elastic bandage or plain bandage secured by plenty of adhesive (cf Figs 5, 6, 7)

The fluffy waste serves as an elastic medium to distribute the pressure evenly over depressions and prominences and it is essential to use enough of it over all bony prominences (especially around the head of the fibula to protect the peroneal nerve)

The pressure is actually applied with the external bandage, and it may be wrapped very tightly if there is sufficient waste underneath it to distribute the pressure evenly Adhesive is wound on spirally from rolls and it usually requires at least one full roll for an adult extremity to secure the bandage firmly and prevent it from slipping for several days or more

The fine-mesh grease gauze is No 44 mesh bandage gauze, 4 inches wide with only enough ointment on it to keep it from sticking to the wounds and not any excess. If preferred, finer mesh bandage can be used and it could be silk or rayon It is prepared in rolls, usually by standing 4 rolls on end in a jar placing one pound of ointment on top of them and autoclaving them. As it is sterilized, the ointment melts down through the rolls, about the right amount remaining in the meshes, and the excess collects in the bottom of the jar A number of these rolls of grease gauze are kept in the accident room and in the operating rooms at all times, and the excess grease can be wiped off the outside and the bottom of each roll just before using The type of ointment that is used is probably not very important, except that it should be harmless and mildly antiseptic Plain petrolatum may be used though it is not antiseptic and has a tendency to macerate (which may be an advan



FIG 7 Type of pressure dressing used in extensive burn (wounds treated in same manner as in Figure 5 after preliminary treatment for shock) This patient received blood transfusions in the veins of both ankles before during and after débridement Pentothal Sodium anesthetic was introduced through transfusion tubing

tage early, but is a disadvantage later with new epithelium from the edges or with young skin grafts) Fairly satisfactory ointments include 4 per cent xeroform, or 5 per cent scarlet red, in petrolatum

When sufficient pressure is applied to the upper portion of an extremity, any exposed distal portion is apt to swell, so that it is best to include it in the pressure dressing (leaving the tips of fingers and toes out, if possible, so that circulation can be observed) The bulky pressure dressing is in itself sufficient splinting in most instances, though wooden or metal splints may be incorporated if desired (especially in positioning hands)

The second dressing is done whenever the first dressing becomes dirty or loose, or when it is thought that the patient's comfort can be increased by doing it There is no established time interval for doing it, though it is often done from 5 to 8 days after the initial dressing As in the first dressing, the work is done in the operating room under light general anesthesia, with all usual sterile precautions If there is a coating of serum on and about the wounds, this is washed off with soap (or a detergent) and water Any new blisters are trimmed off, and any slough present is carefully palpated (with a sterile glove, of course) to see if there is any pus beneath it The wound edges are examined for cellulitis, and an attempt is made to move passively any joints which have been included in the dressing If there was any doubt as to the depth of the burn in various areas at the initial dressing, usually the answer will be evident at the second dressing Often a decision can be made at this time as to when the slough should be excised, and whether it should be done in stages or all at one time. Factors influencing the decision are the general condition and the age of the patient, and the size and the location of the areas to be excised In general, the slough is only a necrotic culture medium which is delaying grafting, and it is best to get it off as rapidly as the patient's condition will tolerate. If the burn is of moderate size, often it can be completely excised at this time; in more extensive burns it may be wise to débride one extremity at each dressing (preferably under tourniquet), or some similiarly staged plan. In very extensive burns it may be necessary to wait a few more days until there has been some spontaneous loosening of the slough, so that removal can be accomplished with less blood loss, even here, it is not necessary to wait for complete spontaneous separation.

If the burn, or some part of it, is to be débrided, usually a blood transfusion is started If débridement is to be done on a large part of an extremity, a pneumatic tourniquet is applied as high as possible This is done by elevating the extremity to the vertical position, placing a folded sterile towel around the upper portion, applying the pneumatic tourniquet over this, covering the latter with a folded sterile towel clipped in place, squeezing blood out of the extremity by wrapping a gauze roll tightly from the distal end to the tourniquet, and then inflating the tourniquet

On long flat surfaces, the slough is sliced off in wide long sheets with a graft knife, staying in the level of the junction of the dermis with the subcutaneous tissue. On some irregular areas, such as the hands, the face and the feet, ordinary scalpel dissection is used As the slough is removed, cloudy fluid usually drains off, this may be partly serous or lymphatic exudate, or partly liquefied fat However, fat is not excised, unless it is definitely necrotic

In areas where a tourniquet cannot be used, active surgical assistants can prevent much of the blood loss by coming in right behind the knife with weak adrenalin compresses (1/5,000 on gauze flats) and making firm pressure As soon as a moderate area has been débrided, larger pads are applied over this, or a gauze roll is wrapped around where possible, in any event, cutting is stopped, and firm pressure is made until

hemostasis is obtained Then the débridement is resumed

The patient s general condition is checked frequently, and the cutting is stopped before he shows evidences of going into shock These patients may have had considerable shock immediately after the burn and do not stand repeated episodes of shock well Enough débriding for one sitting can usually be done in 10 to 20 minutes of expeditious work, and it should rarely be prolonged over 30 minutes With the above precautions it is generally possible to get the slough off early in the postburn phase without setting the patient s general condition back too much. This is one situation where it is well worthwhile to trade 1 or 2 units of blood for 1 or 2 weeks of time a few weeks can seem like an infinity to a patient with a raw or necrotic burn, and he probably would deteriorate further in this time

The second dressing is applied in the same manner as before with pressure and with fine mesh gauze next to the wounds However one may elect to use a wet dressing (rather than ointment) if the slough has just been excised if there is cellulitis of the wound edges, or if it is thought that it will hasten separation of the slough without making the patient too miserable In applying a wet dressing a roll of dry fine mesh gauze is soaked in saline (or a mild antiseptic solution such as 1 5 000 aqueous Zephiran" chloride) and wrapped *loosely* around the wounds until they are covered with one or two thicknesses. A single layer of wet gauze flats is then applied, followed by Carrel irrigation tubes and the usual dressing The irrigation tubes are omitted sometimes and several thicknesses of wet gauze flats are used with the dressing covered with some waterproof material to decrease evaporation.

Subsequent dressings are done every 2 or 3 days in the operating room under general anesthesia. A combination of intravenous Pentothal Sodium and mask nitrous oxide seems to be the most satisfactory on our service with the patient s awakening as the dressing is being completed and being ready to eat the next meal Trichlorethylene (Trilene) can also be used

If wet to-dry dressings have been used it may be necessary to soak loose gently the layer of fine mesh gauze next to the wound Grease gauze dressings usually come loose quite easily and with little bleeding

In an area that has been débrided satisfactorily at the last dressing the appearance of the wound surface on close observation may be that of healthy glistening yellow fat. If the observer steps back a few paces, the surface has a pinkish color, due to the fine skein of new granulations over the surface This is an ideal bed on which to apply skin grafts and there is nothing to be gained by waiting If the patient's general condition is good split skin grafts are cut in as large sheets as possible, applied and 'snubbed-on with the new dressing If the patient s general condition is precarious homografts may be applied in the same manner

If an area débrided a few days before has spots or sheets of dull, brownish yellow fat (sometimes almost leopardlike in appearance), these are sliced off, and grafting is postponed Areas of dead fascia, tendon or other necrotic tissue are excised similarly

In instances where the débridement is staged, one may be grafting one area and débriding another at the same operation In this connection it must be remembered that graft-cutting causes some blood loss and postoperative oozing of serum from the donor area

Areas that are clean and are to be grafted at this operation are washed off with plain saline and not with soap containing hexachlorophene This latter substance, plus ether, may be used on the surrounding skin on any remaining burns not to be débrided at this time and to cleanse the donor skin before cutting grafts

In reapplying dressings, wet dressings are

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usually employed over any newly débrided areas, and fine-mesh grease gauze over grafts or any other areas The same bulky, occlusive, splinting, pressure dressings are used until healing has occurred and grafts are reasonably solid

Superficial burns are dressed and cared for in much the same manner, except that cutting débridement, of course, is not done

The occasional appearance of the characteristic foul-sweet-smelling, green discharge associated with *Bacillus pyocyaneus* is discouraging, as it is very destructive to young epithelium or grafts, even though it seldom produces much constitutional reaction It is combated best by frequent and liberal soap-and-water cleansing with occasional application of 10 per cent Mercurochrome, 5 per cent gentian violet or other dye antiseptics Acetic acid has not helped much in our experience

Dressings should be changed as frequently as necessary to keep the wounds clean and to keep infection down A bath of pus over young epithelial islands will destroy them and will convert a superficial burn into a deep burn Once such an infection is established, it is much more difficult to eradicate than to prevent it in the first place The keynote of local treatment is to keep these wounds clean and to keep them covered

Areas in which there has not been full-thickness loss usually will be healed in from 1 to 2 weeks under this regimen but can be kept covered with a little cold cream and a protective dressing for a short time after that

Facial and genital burns are always somewhat of a problem In severe burns of the whole face, the entire head can be wrapped in a firm pressure dressing with ointment gauze next to the skin after the initial débridement, leaving small holes for the nostrils and the mouth (Fig 22) If there is any conjunctivitis the eyes can be irrigated with boric-acid solution, and a mild ointment can be instilled Anesthetics should be used in the eyes rarely and cautiously This initial dressing can be left in place 3 or 4 days and will do much to keep down swelling in eyelids and other loose tissues If the burns seem to be deep (when the initial dressing is removed), another dressing of the same type is applied after washing the face and irrigating the eyes When the burns are superficial, a second full dressing may be omitted, and the areas are just covered with strips of fine-mesh grease gauze These should be changed about every 4 hours, and at that time any crusts or old ointment removed by using pledgets of cotton and fresh ointment Less severe facial burns and genital burns can be cared for in this latter manner without using any initial pressure dressing In burns of the buttocks the patient can lie on a large pad covered with several layers of greased gauze which is changed frequently, with extra cleansing after each bowel movement Frequent tubbings or sitz-baths are most helpful in the care of burns in the genitorectal area

Prevention of the destruction of any remaining deep glandular epithelium is one of the principal objects of the method, and every attempt should be made to prevent such injury which may be caused by mechanical trauma, strong chemicals or infection Occasionally, areas of apparently obvious full-thickness loss will contain enough of this deep epithelium to give rapid and stable healing This occurs most often in adults on the back, the sides of the chest wall, the scalp and in the beard area of men For this reason, any cutting débridement should be postponed longer than usual in these areas

COAGULATING OR "TANNING" METHODS

At one time some observers believed that toxic split-protein products were absorbed from burned skin, producing a general toxemia, and that it was therefore desirable to coagulate or "tan" the burned area to prevent this absorption Various protein pre-



FIG 8 (*Left*) Fairly clean and dry tannic membrane with patient comfortable (*Right*) Same membrane 8 days later with dirty pus discharging from cracks and patient not very comfortable.

cipitants were used, including ferric chloride picric acid, alcohol aluminum acetate silver salts mercuric chloride various dyes and such crude products as tea ink, takto-cut cutch extract, etc However tannic acid (introduced by Davidson in 1925) with or without silver nitrate (popularized by Bettman) was by far the most popular of these coagulating agents

Experimental work on burns and on split graft donor sites showed that tannic acid definitely delayed wound healing (Figs 12 13) However the death knell to tannic acid treatment was sounded by Wells, Humphrey and Coll (1942) when they showed that tannic acid applied to burns could and did produce liver necrosis and this was subsequently confirmed by others It is now known that this central liver necrosis which was an ordinary postmortem finding in severe burns, was almost always due to tannic acid absorption rather than to the burn

The tannic acid treatment of burns can now be viewed as an interesting historical method but it has no place in present-day therapy nor does there seem to be any reason to resurrect any of the other coagulants (Figs 8 to 11)

OPEN AIR TREATMENT

The open-air or exposure (no dressings) treatment of burns was used on most burns from the beginning of time until the latter part of the last century, then intermittently on a large number of burns until shortly before World War II After about 10 years

in the discard, it has been resurrected with some modifications, and has found several enthusiastic advocates A B Wallace, of Scotland, and Truman Blocker, in this country, along with several other good workers, have done much to study it, modify it and revive it Inasmuch as each worker is experimenting with his own modifications, the method varies considerably in different places at various times Perhaps it should be thought of in the plural, as *methods*, with the "no dressing" factor being the only one common to all

The general idea is to expose the burn continuously to the air, so that any exudate or transudate from the surface will coagu-





FIG 9 (*Top*) Burned child first seen on 4th day after tanning, with high fever, marked sepsis and anemia Several boggy areas in membrane and pus draining from some cracks (*Bottom*) Appearance 1 month later, following chemotherapy, transfusions, surgical removal of part of membrane and daily removal of remainder of it in saline baths Patient is now ready for grafting with bright-red, fine granulations

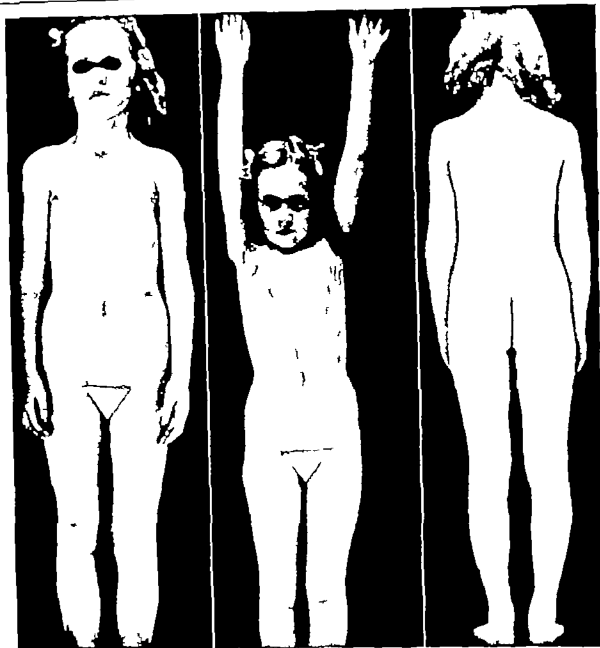


Fig 10 Same patient as in Figure 9 Complete coverage of all raw areas and complete release of both axillae and neck by total of 3 split-grafting operations. The back was used as a donor area.

late This together with the burn-coagulated skin in the deep areas will form a mem brane Some of the advocates of the method feel that this membrane is a barrier to the entrance of outside bacteria and to the escape of body fluids. Other advantages which have been stated are that the method requires less care from physicians and less materials so that it would be more applica ble in the case of massive disasters

Some of the leading workers with this method feel that the advantages are negated if the membrane has any contact with clothes or bedding This may macerate the membrane in which case it is no longer a barrier but becomes food for bacteria. Thus circular burns of the extremities are often put up in traction for elevation and con tinuous exposure. Crucifix splints have been used for some noncircular burns of the upper extremities. Many feel that the method should not be used for



Fig 11 Later views of patient in Figures 9 and 10 after placing an elliptical full-thickness graft across the top of the neck to restore completely the normal angle between the neck and the jaw



Fig 12 Comparison of fine-mesh grease gauze and tannic membrane as dressing for surgically clean partial-thickness loss of skin (thick split-graft donor areas) Patient shown after 2 weeks with left thigh donor area entirely healed and without dressings (treated with fine-mesh grease gauze) Tanned donor area on the right thigh is clean and dry, but the membrane has not separated One edge of the membrane subsequently became infected, and the right thigh required 2 more weeks to attain the same appearance as the left Both donor areas were white when first healed (as usual in Negroes), but there was subsequent pigmentation

burns of the trunk, as it is almost impossible to expose them continuously Some advocates believe that this method should never be used for hands or feet Most workers state that the method should be discontinued as soon as the membrane begins to disintegrate, or surgical removal is begun—that the method is not good for granulating

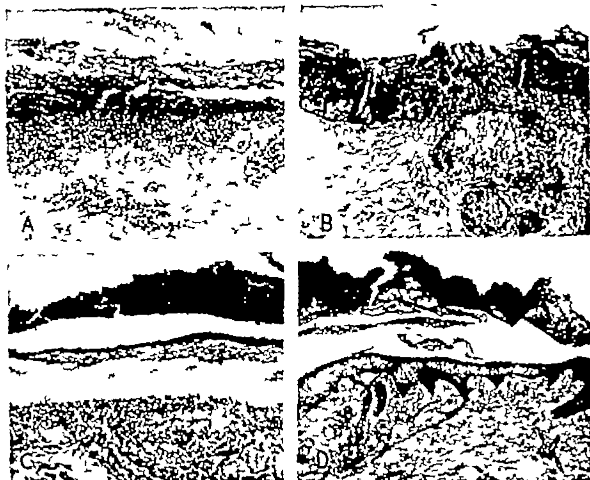


FIG 13 Healing under tannic membranes. (A,B,C) Biopsies of tanned donor area of patient in Figure 12 (A) Third day with no surface epithelium (B) sixth day with no surface epithelium, but apparently activity in remnant of follicle epithelium, (C) ninth day with thin surface coverage of poorly differentiated epithelium. (Compare with Fig 40) (D) Tanned superficial burn biopsied on ninth day New epithelium beginning to differentiate into layers and to form rete pegs. Most of the dermal structures were not destroyed in this burn

wounds However, Wallace states that he has used it on occasion right on through the grafting period

Since exposure is not recommended generally for granulating or grafting periods and there are a number of limitations during the initial period most advocates feel that it does not have universal application For instance one observer who visited a leading service which uses this method reported that out of 11 burned patients on the service 9 had large dressings on—because they were in the granulating or grafting phases or were unsuitable for initial exposure

Some exposure centers have kept their patients in individual rooms in "burn divisions' or in isolated cubicles in "burn wards" with elaborate provisions to prevent infections These have included sterile bed linens wearing of sterile gowns caps, masks and gloves by all in attendance, cleansing of floors with antiseptic solutions, ultraviolet sterilization or filtration of air, specially trained nurses the blowing of penicillin or other antiseptic powders on the wounds, etc. Others have kept their patients on open wards with none of these special precautions but have applied small dressings over any cracks which appear in the membranes

Blocker has reported that he excises the membrane on about the 17th day, and

Wallace on the 16th day Then the areas of deep burn are grafted in the usual manner

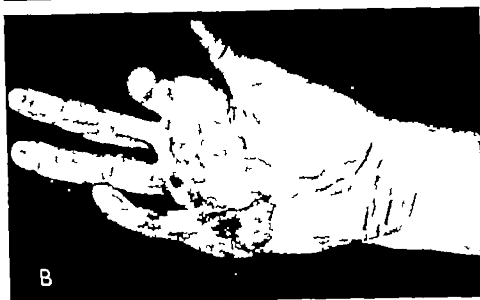
As with other methods, exposure treatment may be subject to misunderstandings or abuse Instances have occurred of superficial burns of a part of one extremity, where the patient has been kept in bed in traction for a long time waiting for the membrane to fall off, such burns could have been treated more comfortably and economically with a pressure dressing on an ambulatory basis, of course Other instances have been seen where indescribable and irreparable hand deformities have occurred from prolonged exposure treatment

Some of the worst cases seen have been circular burns in patients who have been put in bed naked with a sheet-covered frame



FIG 14 Necessity of drainage of deep burns (A) Deep electrical burn of hand treated elsewhere with proprietary oily solution applied on surface Shown on fifth day with deep pus in palm cellulitis of forearm, and hand sealed with coagulated skin (B) Shown after removal of coagulated skin, and drainage Tendons and bones in thumb and index finger were burned Fever and cellulitis subsided promptly after removal of charred skin, drainage and wet dressings up to elbow





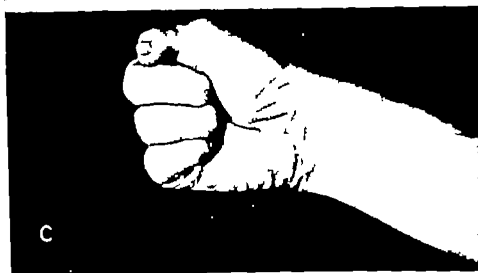


FIG 15 Same patient as in Figure 14 (A) Clean granulating surface ready for grafting 18 days after débridement Grafts carried over small exposed areas of necrotic bone on thumb Amputation of necrotic portion of index finger Late separation of small chips of bone from thumb (B, C) Final result with best function obtainable under the circumstances.

over them and then largely neglected or forgotten In these the under part of the membrane macerates other parts crack and the picture is that of a feverish emaciated patient lying in a pool of pus with accompanying stench (and sometimes flies) The authors recall seeing a "burn division of these patients 20 years ago in a governmental hospital, where the chief reason for isolating the division was to get this mess

where it would not be seen or smelled It is a sad experience to see this situation recur in even one patient today.

These poorly handled cases are not a valid criticism however, of a carefully planned and executed exposure regimen The leading advocates of the exposure treatment today are excellent surgeons who are enthusiastic and capable workers Their cases have been kept clean and comfortable and have been grafted early Practically everyone who has seen their patients has been impressed by the excellence of the care and the final results obtained

If there is any worthwhile criticism of the open-air method, it might be its appeal to the lazy and unversed, to those who are disinterested in burns but would not mind accepting the care of an occasional burned patient if it does not entail any personal labor In such hands it is easy for it to become the "open treatment of neglect"

Certainly there is more than one good method of treating burns Within the limitations proscribed by its advocates, and when properly carried out, the exposure treatment seems to produce very good results in properly selected cases However, early surgical débridement and occlusive pressure dressings seem to have more universal application for deep burns, and for many other reasons, this method is the one used on our own service

REMOVAL OF THE SLOUGH

In deep burns the separation of the slough delays the repair of the wound by skin grafting more than any other one factor This has long been recognized, and everyone working in this field soon tries to devise methods for getting it off the wounds more quickly Thin-skinned areas (as on the forearm or on children) will usually separate faster than thick-skinned areas (as the adult back) Large sheets, for some reason, often separate quicker than small, deep areas (as in electrical burns)

Much experimental work has been done, and this is continuing, to try to develop some nonmechanical method of getting the slough off of burn wounds Pepsin, figsin, trypsin, papain various bacterial enzymes and other substances have been used to try to digest the slough off. Various alkaline preparations have been used to soften the slough, and numerous weak organic acids have been used to shrink it and thereby loosen its attachment to the underlying base In our hands, these methods up to the present have seemed too slow and uncertain—perhaps too much like cutting a dog's tail off an inch at a time

The factor that prolongs illness the most in deeply burned patients is this slough and, on our service, the best remedy for this has been early knife excision—as described earlier in this chapter and in Chapter 5 This one item has done as much, or more, than anything else to shorten the period of illness and hospitalization in these deep burns, and to permit skin grafting before excessive debilitation has occurred

In an occasional critically ill patient, knife excision may not be feasible Even here, it is not necessary to wait for spontaneous dissolution of every single fiber attaching it, but after 10 days or so, a plane can be developed under the slough by alternate spreading and dissecting with scissors, so that it can be removed in sheets with practically no blood loss

The bed obtained immediately after removal of the slough is seldom satisfactory for immediate grafting (unless the excision has been quite deep) Grafts will grow in some cases, but in others there will be enough loss to necessitate secondary grafting later within the same area It is therefore better, as a routine, to apply wet or wet-to-dry dressings for 2 or 3 days until granulations have begun to grow, and then go ahead with the grafting This will shorten the course more and obtain a better final result, in the greatest number of patients

Immediate Excision of Burns and Skin Grafting

At first thought, immediate excision of burns and grafting would seem to be the ideal solution This has been suggested by Wilms (1901), Murat Willis (1924) Wells (1929) Young (1942) Cope *et al* (1947) and others Actually, its application is quite limited, though there is a definite place for it

The first problem is in judging the correct depth of the burn in all of its portions This is fairly obvious in some burns but is not in many others, especially if the observer has watched a large number of burns throughout their healing period Even if it is definite that the full thickness of the skin has been burned through it may not be clear exactly how much of the subcutaneous tissue is damaged beyond recovery Small burns in fat areas, such as the buttocks the thighs or the abdominal wall, can be treated in this manner as it is always possible to excise the burns and then cut out a little more fat until one is sure that a viable bed is present before applying the graft This is especially applicable in small deep burns from molten metals or electricity Thin areas such as the dorsum of the hand the nose the eyelids, etc., allow so little working margin that one should be very cautious about undertaking this procedure in these areas

The advice to solve this problem by excising all questionable areas and grafting them is not good It may be good from the standpoint of economy, or of an overbusy surgeon, but it is not good from the standpoint of the patient, as grafted skin is seldom as good as superficially burned skin that has regenerated satisfactorily

Large burns should not be treated by this method, as the mortality figures will show if it is persisted in The patient must be able to withstand his original burn shock, plus the shock of denuding another area at least as large, plus the shock incident to further blood letting from the burn and the donor area, plus the long anesthetic necessary

Early excision and grafting, as described in the next chapter has proved to be a much better procedure for most deep burns of small and moderate size

5

Early Excision and Grafting of Some Deep Burns

Many deep burns which are not too large can be grafted within a few days after occurrence, and the patients can be back at their normal routine within 30 days after the accident (Plate 3, Figs 16-18)

Superficial burns, however widespread, will heal within 1 to 2 weeks under gentle cleansing care and fine mesh grease gauze pressure dressings Massive deep burns present serious problems in each case, tend to congregate in plastic surgical centers, but constitute a small minority of all burns Numerically, a major problem is that of the best care for the large number of small and

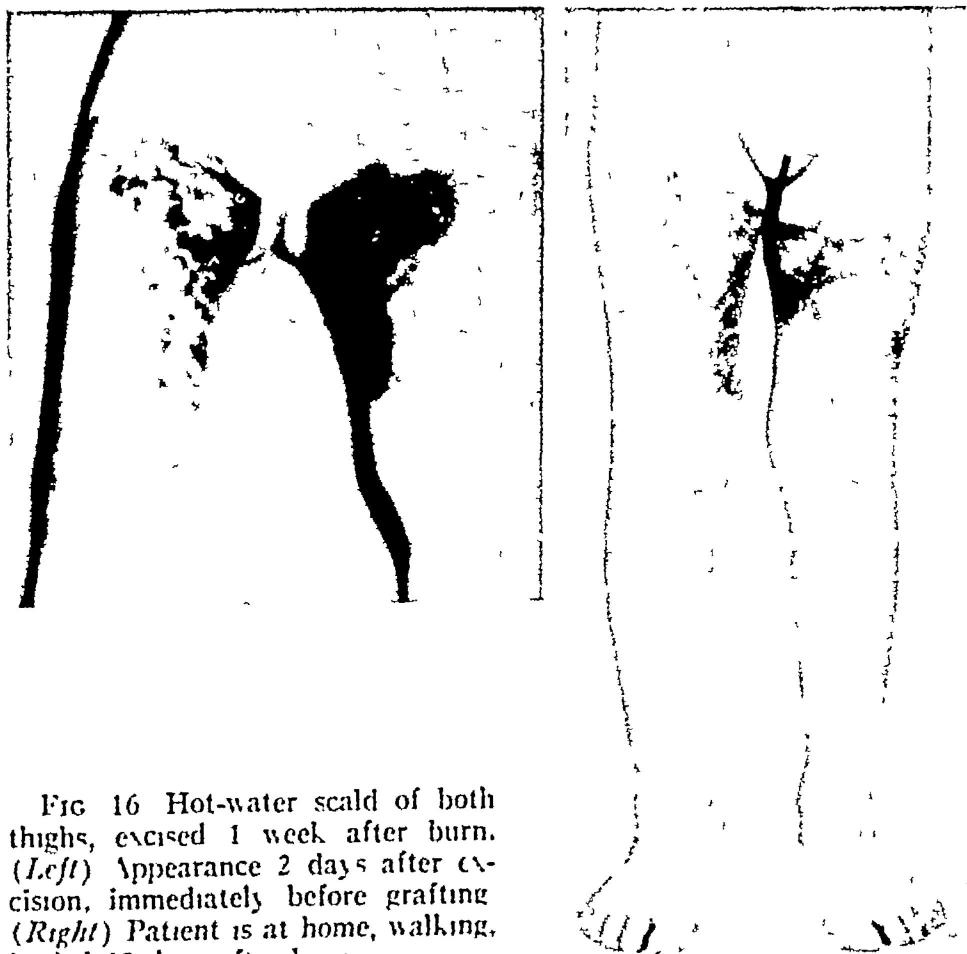
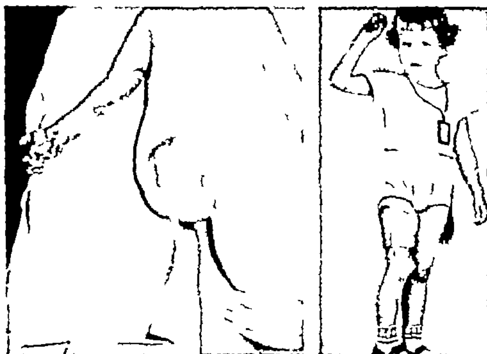


FIG 16 Hot-water scald of both thighs, excised 1 week after burn. (*Left*) Appearance 2 days after excision, immediately before grafting (*Right*) Patient is at home, walking, healed 30 days after burn

PLATE 3



Early excision and grafting (*Left*) Appearance 3 days after burn, with deep areas on thigh elbow and hand demarcated. These were excised at this time and grafted 2 days later (*Right*) Completely healed and back in school 21 days after the burn



Typical appearance of bright red fine, firm granulations which denote that a wound is ready for grafting (See Fig 315)



FIG 17 (*Left*) Gasoline burn of leg first seen after 1 week excision of burn next day (*Center*) Before split grafting 2 days later (*Right*) Back in school and walking 1 month after burn

moderate-sized deep burns that occur so frequently

SMALL DEEP BURNS

Some of these, especially small circumscribed electrical and molten metal burns are suitable for immediate excision and grafting

However a large number of scalds flash burns and fire burns are not As noted before it is sometimes difficult or impossible to judge correctly the depth of the burn in all of its parts—exactly where the tissue will recover where it will go on to necrosis and how deep this necrosis will be Often there may be fairly widespread superficial burns containing a few small areas of deep burn with indeterminate margins

In these instances it is usually best to cleanse the burned area and wrap it up in



FIG 18 Fire burn of leg (*Left*) First seen 1 week later Excised and grafted after 2 more days (*Right*) Appearance 30 days after burn

a fine mesh grease gauze pressure dressing for 2 or 3 days If the total area of all the burn is small, it may be best to do this on an outpatient basis, but burns of moderate size are admitted to the hospital If there is a significant area of accompanying superficial burn, the patient may need observation or treatment for the possible development of shock In either event, it may also be worthwhile to keep the patient on systemic antibiotics for a few days

In 2 or 3 days the exact depth of the burn in all areas will usually be evident, and the patient will have recovered from any shock At this time the dressing is opened for inspection, and if there are deep areas sufficient to require grafting, he may be taken to the operating room that day or the next, and the slough excised under general anesthesia After 2 or 3 days of wet or wet-to-dry dressings, these areas are ordinarily ready to graft

Many of these patients can be discharged from the hospital a few days after grafting, and the dressings and the remaining care are done on an office, home, or outpatient basis Most of these patients will be healed, without dressings and back at work or in school (many are children) within 30 days

Since these burns can be cured most quickly, economically and with the best final result by the early and skillful use of the knife, there seems to be no advantage in procrastinating or using less effective methods of treatment.

Instances have been seen where these burns have been dragged out with various medical treatments with great prolongation of pain and disability, and decimation of the family's financial resources It is hoped that these all belong to the past, as such a procedure is difficult to justify at the present time

MEDIUM-SIZED DEEP BURNS

Practically all of these will require immediate hospitalization and observation for the possible development of shock However, they are cleaned and dressed as soon as possible, in the operating room under light general anesthesia A few days later when the deeply burned areas are definitely demarcated the burn slough is excised Two or 3 days later, they are dressed again in the operating room If the base is clean and pinkish grafting is done, if there are a few scattered small patches of deep necrotic tissue, they are excised, and grafting is done if there is a considerable amount of deep necrotic tissue present re-excision is done, and dressings are applied for a few more days before grafting

By keeping the blood chemistry levels, hemoglobin and blood volume up, transfusing during operations and minimizing blood loss from recipient and donor areas at operation, it is usually possible to excise all of the slough at one operation and graft all the raw areas at the second operation This presupposes that the operative work will be done as directly as possible with a minimum of waste motion and time However, it will be necessary to stage either the excision or the grafting on a few patients In most instances, however, it will be possible to get the patient healed with grafts and out of the hospital in 3 to 6 weeks, and without dressings then or shortly thereafter.

This early, definitive, surgical, method of taking care of these patients will do much to eliminate or minimize various complications and any secondary work Some of the things that may be decreased or obviated include chronic pain and debilitation, serious electrolyte imbalances, hypoproteinemia, anemia, complicating respiratory and kidney infections, decubitus ulcers, muscle atrophy, narcotic addiction, stiff joints, invalid mental reaction, physiotherapy and occupational therapy

All of this is subject to the condition that the surgeon can cut grafts and care for the donor areas in such a manner that they will heal promptly and can get complete "take" of grafts applied (cf. Chap. 9)

6

Spontaneous Healing of Burns and Other Open Wounds

In the treatment of all superficial burns and of deep burns too large for immediate or early grafting full knowledge of the spontaneous healing processes is necessary for the best care and results

After the acute shock is over in small or superficial burns there may be a 'lull that follows the storm," but in large, deep burns the patients may show a steady decline until death or until they are covered with skin whichever occurs first (Plates 1 and 2 Fig 1)

When a claim is made that a chemical will produce healing without scarring, apparently the healing processes are not understood Knowledge of these processes seems to be essential to the rational planning of care during this period Probably not all the important facts are known and those that have been learned have been accumulated quite slowly Laboratory animals are not very similar to the human in skin and subcutaneous arrangement and it is thought that human biopsies have been of the most direct value Daily gross observation of wound healing in a large number of these patients has been perhaps most instructive of all.

HEALING OF SUPERFICIAL BURNS

When redness only has been present during the early days, it is probable that only the superficial layers of the epidermis have been destroyed and they are replaced by the normal constant outgrowth from basal layer or stratum germinativum A a few days, the necrotic layers "peel" and replacement probably will occur w out any scarring visible even with a ma fying glass It is difficult to see the v of any strong chemicals in these instan and it is thought that simple bland (ments or lotions do as much good as thing

Blistering may apparently occur wi the epidermis in the derma, or occasio even in large bullae between the derma the subcutaneous fat Hence, its pres may denote anything from the most su ficial type of burn to full thickness lo skin. Often, when blisters are trimme and the surrounding loose layers are moved in sheets, the remaining base al exactly resembles a fresh donor site a thick split graft. This base is red d with white stumps of hair follicles scatt throughout Healing seems to occur these hair follicles in the same mann in donor sites (cf Chap 8) by outgr and dedifferentiation of the epithelium process may require from 1 to 2 weeks the surface being quite red for several w or months afterward and finally bleac out The final appearance is similar to of a donor site If the graft or the burn denuded only the superficial part of derma the final appearance may be (normal with differences in the textur



Fig. 19 (*Left*) Superficial burn with redness, blisters and edema. Patient treated with cleansing, débridement and fine-mesh grease gauze. Healed in 10 days. (*Right*) Final results shown 1 year later with much the same appearance as a healed donor site from a very thick split graft

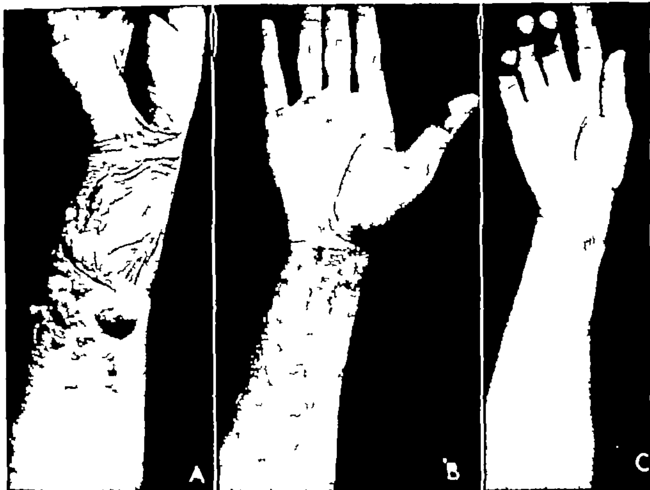


FIG 20 Superficial burn shown (A) immediately (B) 3 months and (C) 10 months later Treated by débridement and dressings with fine-mesh ointment gauze It is difficult to see how any strong chemicals facilitate healing in this type of burn

the skin apparent only with a magnifying glass However, if most of the derma has been removed or destroyed the healed area may be of a lighter color and may present an "orange peel surface with apparent enlargement and depression of the hair follicles (Figs. 19 to 22)

In the Negro if nearly all of the derma is removed by cutting a graft or by a burn the area may heal in the usual manner and time but may be completely white at first *Pigmentation* may occur in the more superficial areas during the next 4 to 6 weeks but the deeper areas often remain lighter or even white permanently This may mean that the more superficial cells in the hair follicles are capable of better dedifferentiation than those down near the papillae

Thick split graft donor areas seem to be ideally suited for the study of healing in this type of burn (Fig 12) The average donor area will be completely healed in about 8 or 9 days if it is not contaminated and is covered with fine mesh grease gauze though it may be desirable to protect it with a dressing for a few days longer Such a donor area heals most quickly if the original dressing is left untouched through this period The same probably would be true in burns of similar depth if one can be *assured of their cleanliness* In either case if most of the derma is gone infection may be devastating to the remaining deep epithelium and convert portions of it into full thickness loss An infected donor site usually requires about 6 weeks for healing and may have final patchy areas of scarring

Coagulated membranes would seem to be

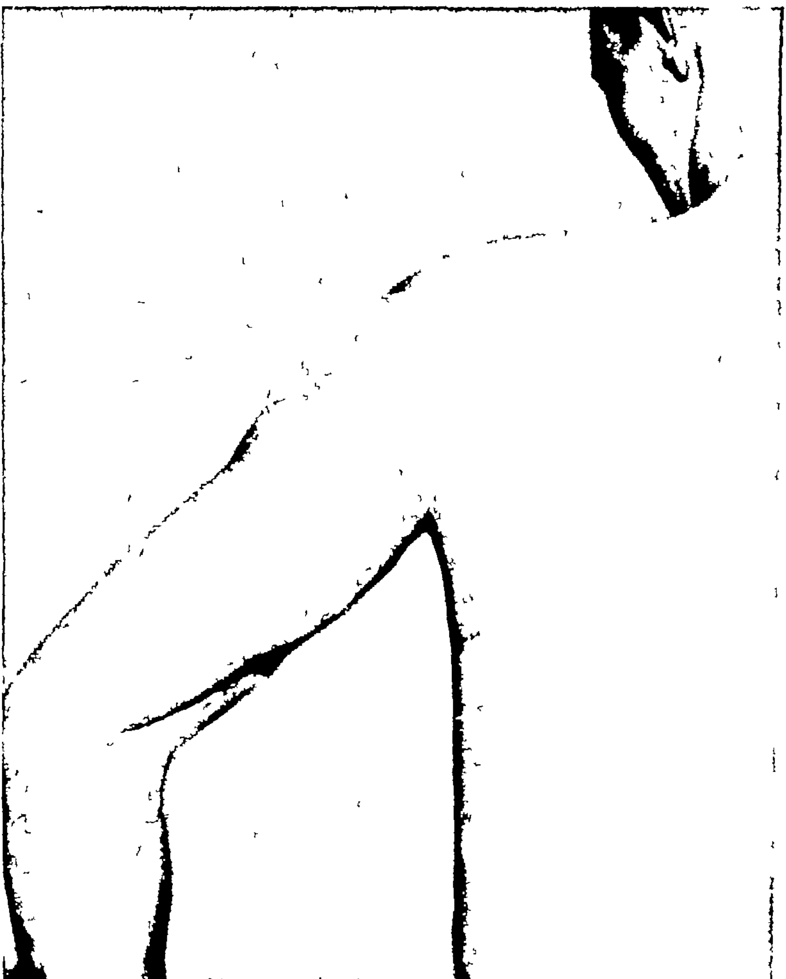



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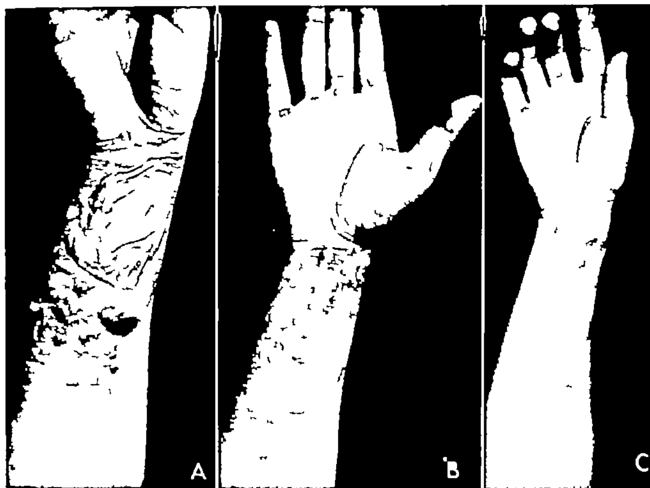


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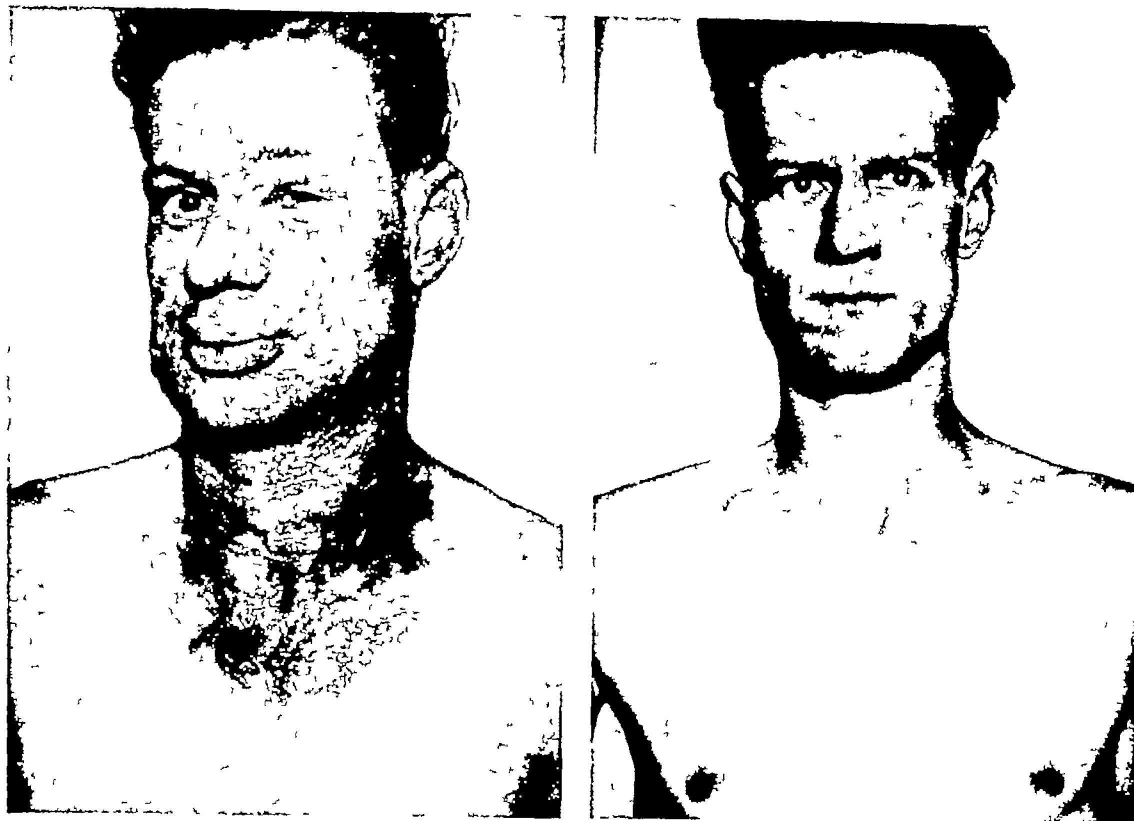


FIG 21 (*Left*) Widespread superficial burn on face (and arm), the patient was in the hospital 11 days with open surgical drainage, including soap and water cleansing, gentle débridement and fine-mesh grease gauze over the entire area (*Right*) Completely healed without deformity or scarring because there had been no full-thickness loss of skin (Internat Abst Surg 67 105-116)

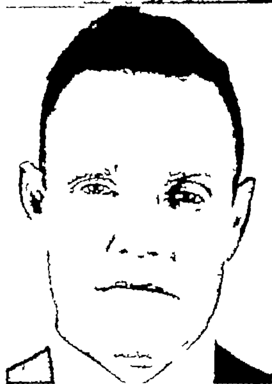
of very little help in these except as a matter of convenience Tanned donor areas on thighs may finally heal satisfactorily, but the crusts do not begin to come off for 2 weeks, and it may be 4 weeks or longer before all are finally healed and the crusts are all off If the areas of donor sites under coagulants become infected, the partial loss of skin is turned into a full-thickness loss, and grafting of the donor site may be necessary This is comparable with the infection of second-degree burns under coagulants so that they are turned into full-thickness loss

Considerable laboratory work has been done on our service with standard superficial burns in mice, to test the effect of various dressings and chemicals on their healing The results were approximately the same as those obtained in clinical observation of a large number of nonstandard superficial burns in human patients, on which different procedures and chemicals were tried

The findings indicate the following (1) Nothing was found that would "stimulate" healing or decrease the healing time Quickest and best healing was obtained under secure fine-mesh grease gauze pressure dressings, changed whenever dirty The time was the same for a number of bland ointments, it was 6 to 9 days in humans, and a day or two less in mice Uniform healing without scar was the rule Cleanliness and lack of scabs, crusts, and culture media on the surface seemed to be important (2) Healing was delayed under dry coarse mesh gauze, or when dressings were allowed to be loose and slipping, or dirty for considerable periods If infection supervened areas of full-thickness loss occurred, which were slowly healed by scar (3) Exposure treatment without dressings produced excel-



Fig 22 Total burn of face early cleaning fine-mesh Merthiolate ointment gauze and surgical waste pressure dressing Dressing left on several days and no further ones necessary Early complete healing



lent healing in most mice and humans but often required from 2 to 3 weeks for all of the membrane to come off Infection developed under the membrane on several occasions and in this instance there was widespread conversion to a deep burn with slow healing by scar (4) Many chemicals which have been advocated in the past markedly delayed healing (5) Three new commercial preparations which have been advised recently were tried on mice with conversion of superficial burns into deep ones in 14 out of 15 of the animals who survived (over half the animals died following this treatment)

The above of course furnishes some very good indications for the treatment of superficial burns. Before changing it is probable that new methods should be tried first on animals, then on small human donor sites There are certain pitfalls in the animal experimentation (1) Skin and burns in different species of animals do not always react alike nor exactly similar to human skin and burns (2) The technic of applying and keeping decent dressings on animals is difficult Mice have to be isolated individually or they will tear each others dressings off and they have to be kept in glass jars rather than wire cages or they will rub them

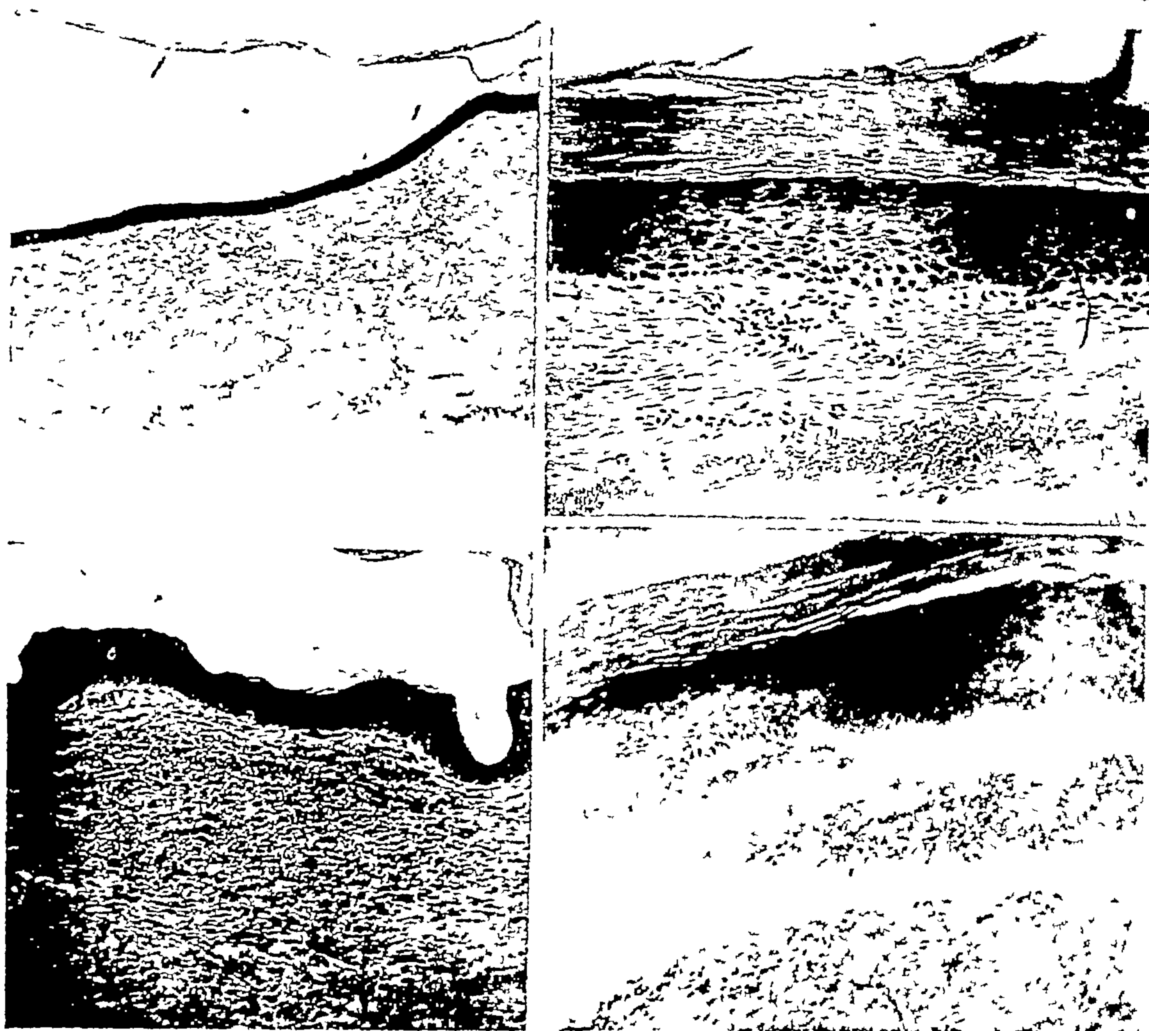


FIG 23 (*Top, left*) Typical scar epithelial healing, with no dermal pad to attach it to the fibrous tissue beneath (*Top, right*) Same thing existing in a scar after 20 years This does become "tougher" but retains the same microscopic appearance (*Bottom, left*) Fresh scar, with red blood cells collected interstitially, just ready to detach the surface scar epithelium (*Bottom, right*) Microscopic appearance of the frequent gross finding of detachment of scar epithelium by hemorrhage Even slight trauma may cause a large surface loss from hemorrhage under this poorly attached epithelium (Ann Surg 115 1166)

off Some larger animals rub them loose or soil them badly it is almost impossible to *even get an abdominal incision to heal without* infection under a dressing in some of these animals

HEALING OF DEEP BURNS

If the full thickness of the skin is lost over a large area, the result is a raw surface or an open wound, regardless of the type of treatment employed The size of these defects is relative for various parts of the body, a loss on the eyelid or the back of the hand of only a few square centimeters *may be as crippling as a very large loss over* the flank or the thighs

Healing must necessarily occur from the deeper tissues and surrounding skin Granulations come up from the deeper structures, fill the wound and eventually lose their vascularity to contract down into a firm, dense scar In the meantime, if healing occurs, thin scar epithelium comes out from the surrounding skin on all sides and covers the surface.



FIG 24 (*Left*) Failure of healing in complete circular full thickness loss Edges quiescent no growth from lower edge (*Center, right*) Complete healing following one thick split-graft operation (Ann Surg 115 1166)

SCAR EPITHELIUM

Skin is a complex organ and the epithelium is the only part of it that regenerates The pad of derma that is really important in giving bearing protection does not regenerate, to any noticeable degree and neither do any of the structures in it such as elastic tissue, sebaceous or sweat glands The thin scar epithelium that creeps across a wound by itself may not be very serviceable as a bearing surface It is thin has no papillae, no hair follicles no glands and may form an excessive layer of keratin with nuclear remnants present far out in it The latter finding may be evidence of a short life cycle of the cells associated with the continual wound stimuli of tension and repeated trauma This scar epithelium may never become very firmly attached to the underlying fibrous tissue so that large areas of it can be detached and lost by trivial injuries or infections (Fig 23)

Failure of healing may occur and is seen most often in circular burns of the extremities and wide-open areas on the scalp In such extremities there may be little or no upward growth of epithelium from the lower skin edge so that the presence of even a narrow longitudinal strip of sk be a big help in spontaneous healing 24 and 26) In the scalp it has bee jectured that the follicles are so far entiated into hair forming structure they do not revert to the production face epithelium so easily as elsewhere body This is not true in the face ho where rapid healing occurs sometime in full thickness losses presumably deep hair follicles that extend clear into the subcutaneous tissues (in mer

Individual variations in the gro epithelium aside from general nutr factors are marked. An occasional p will heal a wide full thickness loss an get permanent bearing function Other heal rapidly but with so much dense fibrous scar that marked deformiti produced (Fig 25) These patient about the most trouble of repair of a this deep scar may have to be remo allow normal function Other patient not to grow any epithelium and can on over long periods developing mor and losing more body fluids all the tim may die

Studies of open wound (ulcer) edge

followed from the above considerations, and one of three pictures is usually found in them (Fig 27)

1 There may be no activity apparent at the edge at all the epithelium simply thinning out and the stratum granulosum appearing to curve around to meet the basal layer, as though a permanent condition of open edge were to be established This might be taken to illustrate an absence of response to the wound stimulus of the open area and usually occurs where there is little fibrous tissue laid down

2. There may be excessive keratosis with



Fig 25 Healing by extreme contracture of axilla, elbow wrist and thumb (completely dislocated) (*Left*) Shown 6 years after burn, during which time the child always had had an empty shirtsleeve, and playmates thought that he had no arm One futile attempt had been made (elsewhere) to release this severe deformity with 8 pinch grafts from the left thigh (*Right*) Rough appearance soon after two split-grafting operations, but complete function of axilla, elbow, wrist and thumb. (McDowell, F, and Brown, J B The surgical repair of burns, Wisconsin M. J)



FIG 26 (*Top*) Deep burn first seen after 4 weeks with multiple islands of epithelium (*Bottom*) Shown after 8 days of daily saline baths and cleansing with rapid healing apparent. The scar epithelium was unstable, however, and was removed when grafting was undertaken. (*Right*) Early single operation Area discolored because shown after 3 weeks. Donor site on opposite side from knee to shoulder healed in 12 days.

Fig 27 Wound edges in unhealed ulcers (A) Inactive edge from an old wound showing no tendency to heal (B) Piling up, but no spread of epithelium laterally from an old ulcer edge (C) Marked breaking up and deep extension of epithelium at edge of an old open wound Possibly related to origin of carcinoma in old ulcers

epithelial débris piled up along the edges, indicating that there has been a response to the wound stimulus exemplified by the short life of the cells, but that they have failed to go on across the defect and effect a closure (Figs 28 and 29) This condition has been diagnosed erroneously as carcinoma by some pathologists, on the basis of edge biopsies, and they have mistakenly advised amputation for it It is sometimes known as "pseudo-epitheliomatous hyperplasia" but could be called "piled-up ulcer edge"

3 There may be a breaking up of the cells with apparent invasion of the deeper fibrous tissue, and it is presumably in this type of reaction that carcinoma develops. However, carcinoma develops infrequently in comparison with the numbers of burns that occur It occurs most often in areas that are prevented from collapsing, such as the scalp, or in large, dense fibrous ulcers that are broken open repeatedly, especially on the backs of knees and thighs (Fig 30).

Deep fibrous healing is presumably the



Fig 28 Hyperkeratotic edges, unhealed after 17 months. Patient was in bed for the entire time and spent $1 200 on a single proprietary ointment advertised for treating burns Both legs healed in 2 split-graft operations (Surg, Gynec & Obst 60 379)

only mechanism by which defects below the skin level may finally become closed the area filling with granulation tissue that gradually changes to fibrous tissue This dense tissue tends at times to defeat its own purpose by becoming so thick and avascular that it cannot support its own surface or any epithelium struggling across it. In some old leg ulcers calcium may even be laid down in the scar and resemble sequestra roentgenographically (This, of course, may come from adjacent periosteum) Failure to remove this deep scar accounts for many failures of grafts for leg ulcers and other wounds that have been open for a long time Because of the thick, deforming dense fibrous tissue that may go along with rapid epithelial growth and produce early distortion sometimes it is easier to repair the patient who makes little if any epithelial effort of his own but at least does not go into every possible kind of deformity

BURNED TENDONS AND BONES

Burned tendons or bone may keep wounds open for very long periods unless they are removed (Fig 15) Dead tendons may lie at the bottom of a wound for months without

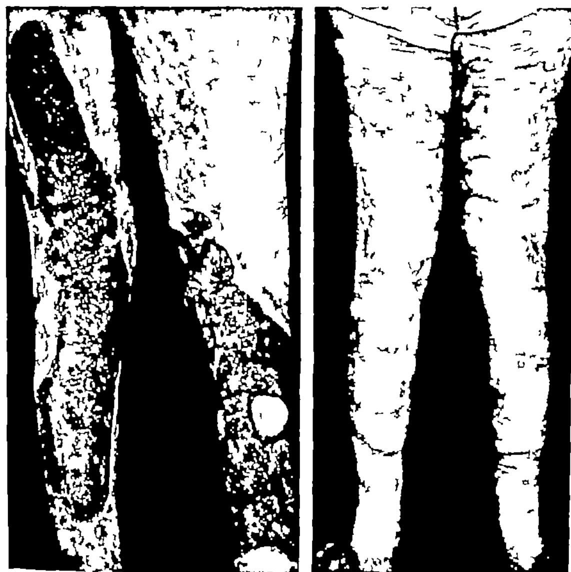


Fig 29 (*Left*) Complete circular loss shown 17 months after gasoline burn No healing took place though the patient had spent $3 000 for medicines and dressings. (*Right*) One operation for each leg and appearance after 1 year (Surg Gynec. & Obst. 63 331)

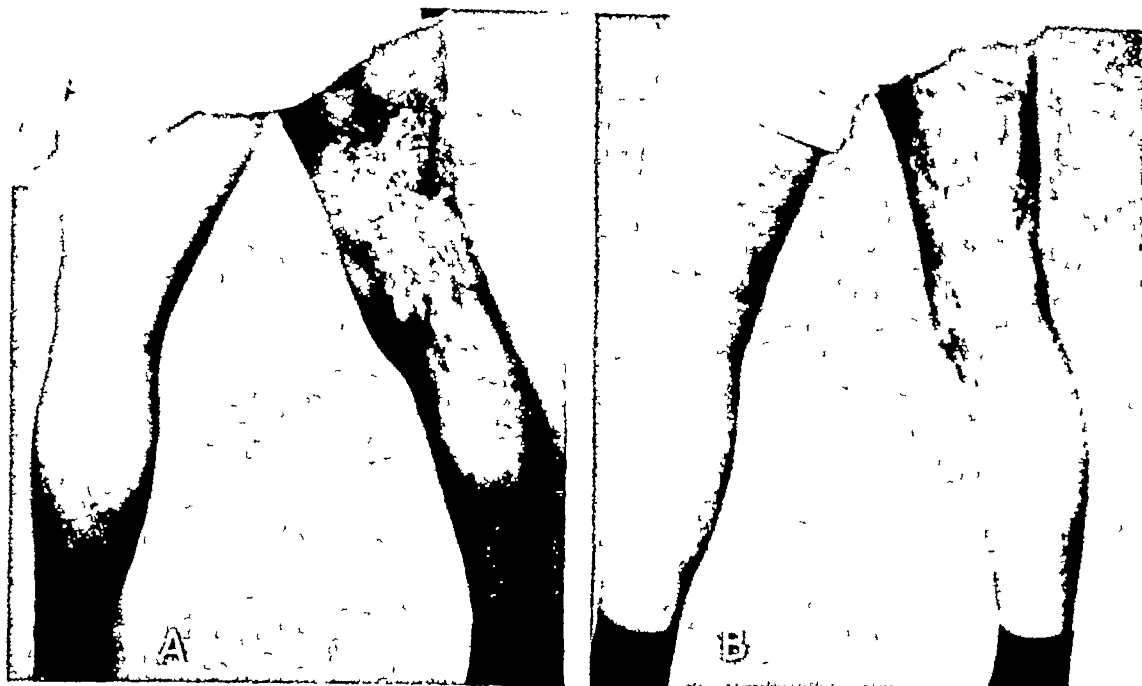


FIG 30 (A) Extensive squamous carcinoma in old burn scar, extending beyond ulcerated edges shown and down to hamstring muscles (B) Two months after excision and split grafting at same operation Graft is placed directly on muscle sheaths but has free motion

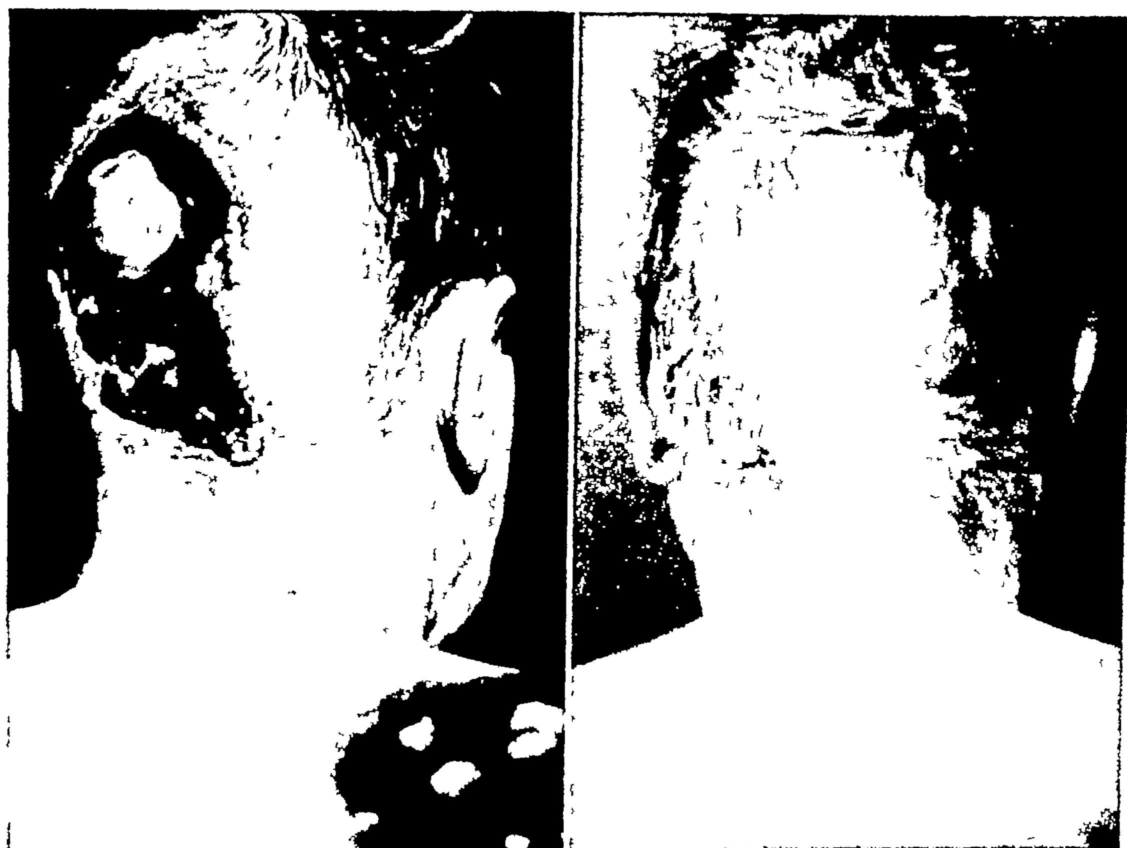


FIG 31 Burns of the shoulder and the scalp, with dead portion of the skull exposed (a few pinch grafts had been laid on the wounds elsewhere) Shoulder and scalp were covered with split grafts in one operation, cutting a drainage hole through the graft over the bone The dead segment of the external table was pried out with a periosteal elevator three weeks later, and a small split graft was laid on the granulations after they appeared The final result is shown at the right, this area has remained healed for 4 years.



FIG 32 Circular burn of the leg from the knee to the ankle with the dead portion of the tibia exposed The entire area was covered in one operation up to the edges of the dead bone Involved bone (which consisted of anterior cortex) was pried out with periosteal elevator a few weeks later, and another small split graft was applied over this area as soon as sufficient granulations were present

any granulations covering them or may become partially covered to form a persistent deep sinus. They should be excised as soon as it is definitely established that they are not viable The bones most commonly involved are the superficial ones, including those of the hands and the feet the tibia and the skull (Figs. 31 to 33) Grafting need not be delayed for months while waiting for spontaneous separation If the exposed portions are small, the grafts can be put on over or around them to heal all surrounding areas When the exposed dead bone is considerable, a preliminary operation can be done to remove it with gouges and chisels. The line of separation is usually definite but in case of doubt it may be better to err on the conservative side Care should be taken not to elevate any of the surrounding periosteum In the skull usually the outer table only is destroyed If it does not show any evidence of separation after a reasonable period multiple drill holes may be put just through the outer table and after granulations have come up through them the intervening fragments can be carefully pried loose However, this is not devoid of danger and in spite of seeming to be a simple procedure should be undertaken only with the most careful consideration If the inner table is also dead it should be removed carefully (often in conjunction with a neurosurgeon) to avoid any tears in the dura, temporary coverage with a split graft may or may not be used but final coverage probably will have to be provided by rotating in a local flap Bone grafting may be done several months later when necessary (Figs. 267 268)



FIG 33 Final result in the patient shown in Figure 32 The patient returned to work in a railroad switchyard

7

Preparation of Wounds for Skin Grafting

BURNS

The preparation of deeply burned areas for skin grafting is a continuation of the early care

The general care is of primary importance and includes the exercise of patience and gentleness and interest in the patient's welfare by all who come in contact with him The patient should be kept free from pain and from objectionable restraints, sedatives should be used carefully, and an interest in surroundings should be developed, especially when patients are children

A firmness of purpose should be maintained that will tend to keep morale on the highest possible level Nutrition must be sustained, and frequent transfusions may be required Repeated plasma-protein and hemoglobin determinations are necessary to determine the need of transfusions, and an effort is made to supply much more than the minimum vitamin requirements High caloric and high protein diets are useful if they are prepared in an appetizing manner so that the patient will eat the food, and supplementary between-meal feedings may be provided The patient should be checked clinically and by laboratory determinations in regard to his electrolyte levels, as often as is necessary, and appropriate therapy should be instituted

The local care of the open wounds has for its object the cleaning up of the areas as quickly as possible and obtaining firm, bright-red granulations (Plate 4) for the reception of skin grafts before damaging contractures have occurred

SURGICAL DRAINAGE CARE OF WOUNDS

If wet dressings are employed, fine-mesh gauze is used as the layer next to the wounds, and saline or aqueous Zephiran may be introduced frequently through irrigation tubes, or they may be allowed to dry out without irrigation tubes. They should be used when there is a considerable amount of slough that is in the process of separating, or when there is any infection, as evidenced by cellulitis around the edges, fever or copious or foul drainage, and it is sometimes advisable to use wet dressings for from 24 to 48 hours before grafting, or after excision of slough Some patients react unfavorably toward them, complaining of pain or the generally disagreeable dampness, or tend to develop maceration of the edges or small pustules in the surrounding skin In such instances, it may be better to omit them or use them at infrequent intervals. The use of silicone ointments on the surrounding skin will prevent most of the maceration When wet dressings are used, it seems better to change them frequently.

Fine-mesh ointment gauze dressings are more comfortable and may be used when there is no special indication for wet dressings They are quite useful when the wounds



FIG 34 Many patients are so comfortable in the baths that they are reluctant to leave them The water can be changed gradually with a slow stream of warm water running in This patient "kicked out 90° secondary contractures of both knees in the bath (*Surg Gynec. & Obst* *60* 379)

are relatively clean and while waiting for the granulations to develop in sufficient quantity and become of the proper character Plain petrolatum is not used because of a tendency to macerate, but almost any powder in it, such as 4 per cent xeroform 5 per cent scarlet red, 5 per cent boric, 1 2 000 Merthiolate, etc., will tend to prevent this Some mild antiseptic seems to be desirable but it is not possible to make any long range forecast as to the best one When petrolatum is used as a vehicle all excess ointment should be removed from the gauze and only enough left on to prevent sticking Some of the "greaseless ointment" bases can be used but they tend to dry out considerably after autoclaving and may not come loose from the wounds easily unless they are soaked When the wounds are clean enough for the use of grease gauze, usually they can go 48 hours between dressings

TREATMENT OF OLD BURN WOUNDS

Patients with old burns may come in for definitive care after weeks months or years with persistent open wounds or with mixtures of scar contracture and raw areas Some of the worst situations occur when both the original burn wounds and "too deep skin graft donor areas are open and infected

If the wounds are reasonably clean, they can be prepared for grafting in a few days by washing with soap and water and ether under general anesthesia and applying firm fine mesh gauze pressure dressings (either wet or grease gauze) Exuberant, pale, coarse granulations will lose their edema and infection and become a fine, flat bright red bed

Wounds that are heavily infected and covered with multiple layers of old grease scales and scabs may require more gross cleansing at first and more time The same is true of old infected burns with membranes on them.

Tubbing may be the most efficient and convenient way for gross mechanical cleansing of many of these wounds (Fig 34) All of the dressings down to the fine mesh gauze can be clipped loose in bed and the patient can then take this inner layer off while in the tub or all dressings can be removed in

the tub if desired A careful search should be made for any crusts of serum which are adherent to the wounds or the surrounding skin If any are found they should be removed Over-all washing with white soap and water, using gauze flats for wash cloths, usually is indicated but should be done as gently as possible Due attention is paid to the surrounding skin, and if quite hairy it may be shaved Abscesses can form within granulations, and there should be careful inspection for any areas of bogginess After the cleansing has been accomplished, fresh water can be run in, and the patient may be allowed to remain as long as he is comfortable Sometimes burns of even the upper extremities the axilla and the neck may be cared for conveniently in the tub, but can also be cleansed otherwise, utilizing the same principles The bath saline is kept at a comfortable temperature with about 2 pounds of cooking salt in each tubful, but both temperature and salinity can be varied according to the patient's comfort

Secondary contractures can almost always be straightened by the patient's own voluntary efforts while in the tub, though considerable persuasion and supervision may be necessary This is well worth while, and it is not unusual to see a secondary 90° knee contracture "kicked out" with only a few treatments in the tub Primary contractures are held by firm, dense scar and will not yield to exercises or stretching, but many of them have some accompanying secondary element which may be relieved It is usually not advisable to use either skin or skeletal traction at this stage

Pressure dressings are a fundamental in the preparation of wounds for skin grafting This continuous pressure probably does most to convert edematous, pinkish-gray, coarse granulations into firm, bright-red, fine ones The pressure is applied by the external bandages which should be large and heavy enough for the purpose Several varieties have been used, including the commercial elastic, woven ones (e g, "Ace'

bandage) muslin bandages and "gauze rolls" The gauze rolls consist of 8-ply gauze, 4½ inches wide which may be purchased from surgical supply houses in long rolls however, it is usually cut into 5 yard lengths for convenient use (Fig 35) Narrower widths may be of advantage with children while 6- or 8 inch widths may be easier on the trunk of an adult. The crinkly conforming gauze rolls that are now available are very useful for these pressure dressings The rolls are wrapped tightly around the involved areas and then snubbed on with plain bandage and plenty of rolls of 1 inch adhesive, wound spirally around upward and then back down.

Some medium is necessary to distribute the pressure evenly in crevices and prevent too much pressure on any bony prominences. Marine sponges were used for years for this purpose, but they have been replaced by ordinary cotton surgical waste which is more efficient easier to use and cheaper (Fig 36) The waste is autoclaved at 20 pounds pressure for 30 minutes It should be picked apart and "fluffed out" just before use

Elevation of the involved areas is generally accepted and needs no further comment

Splinting is accomplished to some degree by the bulk and the firmness of a pressure dressing but additional aluminum or wood splints may be incorporated if desired

DISPOSAL OF ESCHARS AND MEMBRANES

Infected membranes occur in many deep burns where exposure or coagulating treatment has been used and the disposal of this membrane and the control of the resultant infection may be a problem The membrane may be opened in several places and any loose areas detached, and then mild antiseptics on packs used as outlined above or the antiseptic may be applied in ointment form, if there is not too much discharge and cellulitis In other words open surgical drainage plus antibiotics is again the treatment If there is much slough under the membrane Dakin s solution may be used for a few days. As soon as the whole membrane begins to loosen, the patient may be taken to the operating room and the entire

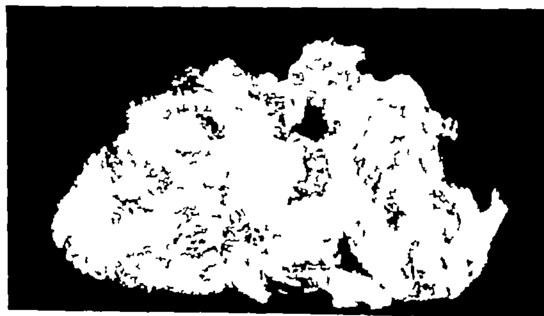


Fig 36 Bleached white cotton "surgical waste supplied by C Gilbert Walworth Co Philadelphia Although this is the nicest, yet any clean bleached short fine thread, surgical s waste (supplied by companies that handle wiping materials) can be used as could other soft compressible materials.

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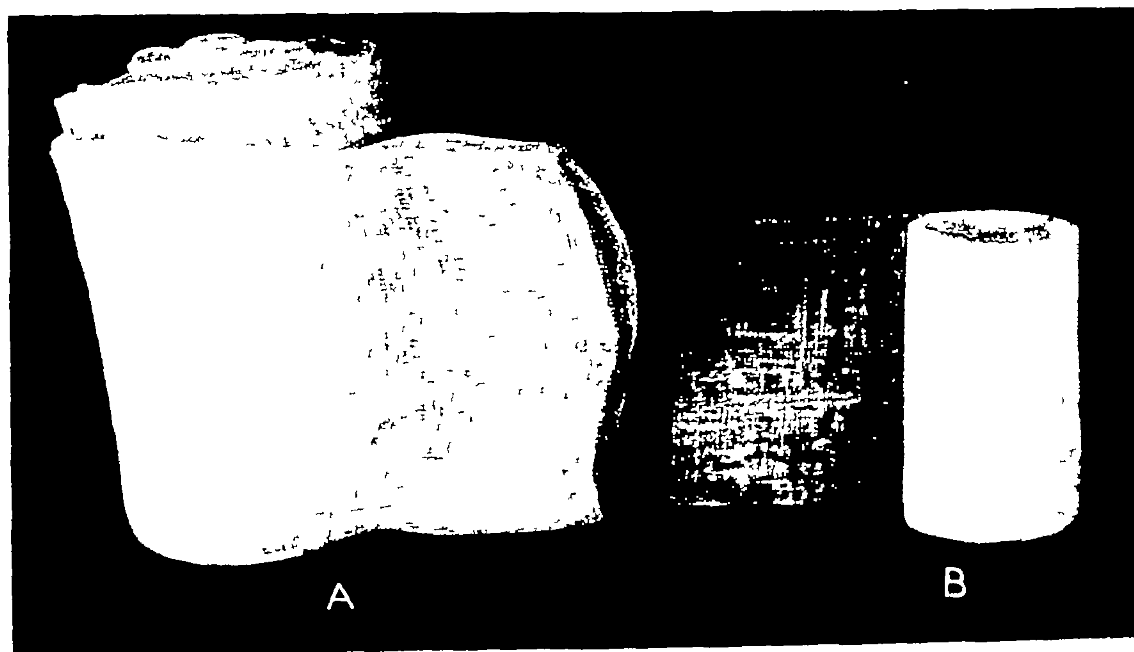


Fig. 35 (A) Gauze rolls which are used for the application of pressure in large dressings (B) Fine-mesh (No 44) bandage gauze which is used next to all open wounds and grafts, either wet or with ointments Granulations do not grow up through the meshes of this gauze and it can be removed with nearly no pain or bleeding Fine-mesh gauze has been used since 1929.

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thing removed surgically, much as an ordinary burn slough is removed When the membrane is clean, as it may be on a superficial part of the burn, it may as well be left on until it drops off, even if this takes some time, because cutting or pulling it off only disturbs the healing

PREPARATION OF CHRONIC ULCERS FOR GRAFTING

Old ulcers, whether originally due to burns, specific infections, mechanical trauma or circulatory insufficiency, assume many common characteristics They are apt to have a dense fibrous base, to be covered with a poor quality of edematous granulations, may have some slough present and are almost invariably quite dirty when first seen

A careful history and examination are in order to determine all etiologic factors and to see if any of them are still present and require treatment Biopsies can be taken if there is any question of the presence of a tumor, cultures should be taken if some unusual type of infection seems probable If the ulcer is below the knee, the patient is kept in bed with the leg elevated throughout the preoperative and the postoperative periods

The ulcer is cleansed thoroughly with soap and water, and the surrounding skin is shaved, washed with soap and water and usually some fat solvent such as ether or benzene If very much slough is present, it is desirable to take the patient to the operating room and débride it under anesthesia Small amounts can be removed by local débriding in the dressing room

Wet fine-mesh gauze pressure dressings are applied daily, with new cleansing each time Saline is used on larger wounds, but 1 5,000 aqueous Zephiran or 1 1,000 aqueous Merthiolate can be used on small ulcers Ten per cent Mercurochrome can be painted daily on small wounds that seem to be heavily contaminated with *Bacillus pyocyaneus* However, mercurial poisoning is possible when any of these mercurial drugs is applied repeatedly, especially on large wounds or on patients who have renal damage

Very large wounds may often be cleansed more efficiently in saline baths, with the surgeon or the responsible house officer putting on sterile gloves and thoroughly washing the area himself, rather than leaving it to more inexperienced personnel Systemic antibiotics may be used for a few days before and after grafting

There is often an increase in the discharge from such a wound during the first 2 or 3 days of the above treatment This may be due to new activity in an old sluggish wound in which the rather feeble granulations have been living in a sort of symbiosis with myriads of contaminating organisms As the new granulations multiply under the cleansing care and wet dressings and establish control over the local flora, the drainage will usually diminish in amount

The initial appearance of some of these old, quiescent ulcers may be deceptive, and their true character may be more apparent after a day or two of wet dressings In general, all except very small ulcers will require a minimum of 4 or 5 days of the treatment described above to attain maximum conditions for the good growth of grafts

CRITERIA OF TIME TO GRAFT

Most deep burns, when treated by surgical drainage and débridement, can be made ready for grafting within a short time Surgical drainage and pressure dressings usually result in wounds with bright-red, firm granulations, free from surrounding cellulitis (Plate 4) The discharge should have moderated in amount and should not have an offensive odor

Bacillus pyocyaneus occurs very frequently in large wounds, especially if they have been unclean over a long period, and though it does not appear to hurt the patient or the wound, it is exceedingly bad for

skin grafts If the open surgical drainage débridement and daily cleansings do not suffice the application one or two times a day, of 5 per cent gentian violet, 10 per cent Mercurochrome, or other dye antiseptics may help if one is sure first to get rid of all débris with soap water and ether The presence of *B pyocyaneus* can be recognized by the green color on the dressings and the peculiar musty nauseating odor If there is any question a day or two of wet dressings will help to decide the issue The bacillus may lurk in greasy scales on the wound edges, and the meticulous daily removal of these with ether will help Acetic acid and some new antibiotics which have been ad vised for it have been somewhat disappoint ing

Bacteriologic studies have shown that it is probably easier to get sterile cultures from small wounds than from very large open areas Many wounds have been grafted when from the appearance of the granula tions they have been thought to be suitable for operation and successful takes" with a minimum amount of cellulitis have been obtained when preoperative cultures have shown multiple organisms. Most culture technics show the variety but not the quan tity of organisms present and it may be easier to get grafts to take in the presence of a few hemolytic staphylococci or strepto-cocci than in large numbers of *Bacillus pyo cyaneus* or *Proteus vulgaris* For this reason the clinical appearance of the wound may be the safest guide as to the total amount of infection present.

The general condition of the patient is obviously important He should be relatively free from "toxemia and nearly afebrile The hemoglobin and plasma protein levels should be up within reasonable limits How ever the large wounds in themselves can be continuously debilitating and when it is thought that the patient is in the best con dition *that can be attained* the grafting may be done In desperately ill patients who are constantly "slipping," homograftir may be almost invaluable for a temporai respite (See below)

A thorough Carrel Dakin technic is ui doubtedly an advantage at times, but it cai not replace careful evaluation of the gener condition of the patient and of the gross aj pearance of the granulations and surroun ing tissues

Interest in early grafting has been vei worth while and gratifying, but it should n push the surgeon into grafting wounds b fore they are ready The few days more th may be necessary to free the wound of sma skeins of necrotic, sloughing derma may r ward the surgeon and the patient by pr ducing a full take of the grafts obviati another operation and actually reducing tl total amount of hospitalization requir before complete healing

HOMOGRAFTS AS EMERGENCY BIOLOGIC DRESSINGS

It may be a lifesaving process to go to t trouble of applying large sheets of split hom grafts in patients who cannot stand a lo operative procedure and are slipping" dai from debilitation and pain. Homografts ta almost as well as autografts and survive fr 3 to 10 weeks. During this period the patie is given a respite from pain and dressings l general condition picks up and there is a sti ulus to his own epithelization so that comple healing may occur even after absorption the grafts This notable increase in wou healing has caused some observers to thi that homografts survive permanently T grafts absorb in a rather clean fashion ju fading away from the third week on witho infection usually and leaving a clean gran lating base (cf Chap 28)

Four Phases of Care of Deep Burn Homografting may be considered as the se ond in 4 phases of care and rehabilitation extensive deep burns First is the preventi of shock and the maintenance of fluid balan nutrition and blood elements. Second is hom grafting for emergency biologic dressings open areas to tide the patient over the critic

period, if possible Third is flat surface autografting, to give permanent wound closure and healing. Fourth is final rehabilitation by plastic surgery, including reconstruction of flexion deformities and restoration of hand function Another long and important element of this fourth phase is resurfacing and rebuilding of faces and features to give restoration of the best possible contour anatomy

OCCUPATIONAL THERAPY AND REHABILITATION

This may play a most important part in the outcome of the operation, both from a mental and a physical standpoint, and is especially important for patients with massive burns who are to have a considerable period of hospitalization Together with this, physical therapy, either voluntary or by directed active and passive manipulation, may be of great assistance in preventing and overcoming secondary stiffness of the tendons and the joints

MORBIDITY AND EXPENSE OF BURNS

Morbidity and expense of care of burns can reach huge proportions, and it is to be noted that very few seem to recognize this, including many hospital, insurance and administrative echelons The tremendous amount of work necessary in plain "elbow grease" and in patient care is difficult to realize, even in some professional levels

Ordinarily, the surgeon must assume responsibility for driving the treatment through to early completion and rehabilitation—tolerating no delays except those that are to the distinct advantage of the patient In most instances, it will be found that there is every advantage to orderly constant progression in the repair, and that delays are productive only of more pain, more debilitation and more expense to the patient, plus more total work for all of the personnel concerned

8

Varieties of Skin Grafts

Free skin grafts may be differentiated from pedicle flaps in that the former are taken *completely loose* from the donor site and transferred to the recipient area at one sitting Repairs by free grafts are necessarily more direct and expeditious than those by pedicle flaps and the results are often better (*Fig 37*) but this will be considered in greater detail later

Free grafting is apparently made possible by the fact that skin can maintain its viability for a short time without any blood supply and for an even longer period by osmotic interchange with the intercellular fluids, until capillaries can invade it and supply nutrition One might conclude from this that skin has a relatively low metabolic rate and is capable of adaptation to low oxygen tensions It is possible to keep *free grafts of skin in the refrigerator* at 4 C up to 3 weeks and apply them successfully if sterile precautions are observed However that there are limits to this ability to withstand oxygen deprivation is shown by the



Fig 37 Excision of radiation burn of entire neck and upper chest anteriorly, and coverage with split skin grafts. Shows smoothness and contour that sometimes can be achieved by careful placing of large grafts and by attention to details to get a perfect take Resurfacing only is needed here and the result is far superior to that which could be obtained from any flap





FIG 38 (*Top*) Simple free-hand method of cutting thick split graft, about 75 per cent of the full thickness (11 x 4 in). (*Bottom*) Larger grafts are available in large patients Healed donor sites shown of one graft 36 x 4 inches, and one 30 x 4 inches (Ann Surg 115 1172)

fact that full-thickness grafts from very thick areas (such as the skin of the back) cannot be relied on for uniformly successful "takes"

The types of free grafts most often used are (1) thick split-skin grafts, (2) small deep grafts and (3) full-thickness grafts

THICK SPLIT-SKIN GRAFTS

These grafts are cut in fairly large sheets, consisting usually of one half to almost the full thickness of the skin (Figs 37 and 38) They are perhaps the most widely applicable







FIG 39 Three types of skin grafts (*top*) Ollier-Thiersch graft, with practically no derma, (*bottom, left*) thick split graft of about 80 per cent of the full thickness (used in 1932), (*bottom, right*) full-thickness graft from adjacent area of same patient Same magnification in all (Ann Surg, 115. 1169)



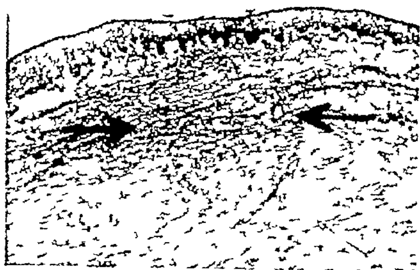


Fig 40 (*Top*) Thick split skin graft used successfully in the repair of a burn (*Bottom*) Biopsy of same graft 1 year later Arrows point to attachment of normal dermal pad May be compared with Figure 23 (Ann Surg 115 1170)

of any type of graft in the repair of burns Huge areas can be quickly covered with them (up to 220 sq in. in one operation and 600 sq in in one patient) and the included dermal pad gives a surface that is stable and will withstand trauma

Synonyms for this type of graft include Ollier Thiersch graft razor graft epidermic graft intermediate graft calibrated graft three-quarter thickness graft blanket graft and implantation graft. This multiplicity of names is confusing and does not add any thing to the work. Ollier and Thiersch were among the first to describe this type of graft but there is some evidence that others were using it at about the same time They described a very thin graft sliced off in small chips with a razor and the name "Ollier Thiersch graft has this connotation to most surgeons Some textbooks contain a microdrawing of this type of graft, showing the skin sliced off just above the bases of the rete pegs of the epidermis and imply that healing takes place from these rete peg stumps. On actual trial it has been almost impossible to cut a graft this thin and if it were it would have very little more value for covering than scar epithelium The dermal pad is probably the most important element of a graft and for this reason it is suggested that the terms razor graft' and "epidermic graft' might also be dropped The recent terms "intermediate graft" and "three quarter thickness graft" do imply that a partial thickness of the skin is being used but do not seem to have any advantage over the established name thick split graft The term "blanket graft has been

used when split grafts are sutured together before applying them Others have diced up sheets of split graft into small chips before applying them and have called them "postage stamp grafts " Neither procedure seems to be useful or desirable The term "split graft" was coined to designate any graft of partial thickness obtained by splitting the skin in two, the idea coming from the operation of a leather-splitting machine in a harness shop The name seems to be sufficiently concise and well enough established to merit its continued use

The dermal pad is one of the essential features of the graft and enables it to withstand trauma satisfactorily in many instances (Fig 40) These grafts have been used on the soles of feet, the palms and the buttocks and have continued to function satisfactorily for many years They sweat, secrete sebum and grow hair, but perhaps the most important parts of the derma for wear are the numerous, interlacing, elastic fibrils which give resilience to the surface The derma apparently does not regenerate at all in a full-thickness burn, and the only portion of it present will be that which is transplanted in the graft

Multiple crops can be cut from very thick areas such as the back As many as 5 crops have been taken from one area with the second crop removed only 19 days after the first (Fig 2) The derma in an adult man's back can be exceedingly thick, as compared with the extremities, and it is probable in these instances that only about one fourth or one fifth of its total thickness is removed in any one graft, though it is possible that some regeneration occurred under these conditions Whatever explanation is correct, this use of multiple crops has permitted very extensive repairs in some patients with limited donor sites available

Areas on which split grafts will "take" include clean granulations or their underlying yellow fibrous base, scar from which the epithelium has been denuded, fat, muscle, fascia, periosteum (but not bare cortical bone), tendon sheaths or peritendon (but not bare tendons), and possibly perichondrium They have been put in many of the cavities of the body, including the inside of the orbit, the conjunctival sac, nose, mouth, larynx and vagina Often the grafts will persist laterally for distances of about 1 cm from their blood supply, and because of this they may bridge over small areas of bare cortical bone, cartilage or small nerves and tendons or blood clots, though one rarely depends on this

Rapid healing of the donor sites makes the work possible and furnishes an opportunity for study of epithelial healing in general (Fig 12) Large areas are denuded under sterile conditions, and the influence of any agent on the rapidity of epithelial healing can be readily noted The resemblance to a superficial burn or to a deep abrasion is evident

In the healing of donor sites, the deep glandular epithelium in the derma spreads out over the surface and entirely re-covers it in 6 days, and often in 6 more days the dressings can be left off In fact, only one dressing is usually done, on the 10th to the 12th day This process is a sort of "dedifferentiation" of the cells of the hair follicles, so far as we have been able to determine, and a gross observation in substantiation of this is the fact that on the palms and the soles, where there are no hairs, healing is slow

The whole process can be studied microscopically in biopsies taken at intervals (Fig 41) Healing is complete by the 6th day, and by the 9th day conversion to squamous epithelium is so nearly complete that papillae are formed, and some keratin is being thrown off This process is apparently the reverse of the original formation of hair follicles It is also something like a reversal of carcinoma formation, and it was thought that a somewhat similar picture might be found if enough healing donor-site biopsies were done This has not been entirely demonstrated because the cells go out so rapidly



FIG 41 Healing of donor sites of thick split grafts (*Top left*) Biopsy 2-day-old donor site—no surface epithelium (*Top right*) Four-day-old biopsy showing deep follicle but no surface coverage (*Bottom left*) Two days later or 6th postopera tive day showing complete coverage with squamous epithelium. (*Bottom right*) Ninth day with normal appearing epithelial surface Rete pegs beginning to develop and keratin being thrown off (Ann Surg 115 1175)

and orderly but suggestions of it have been found

It is apparent that this process is a very delicate one and that irritation of any na ture chemical bacterial or mechanical will prevent healing When this does occur the healing period is changed from 10 days to 8 or 10 weeks and whole areas of the derma seem to melt away It is evident that ex treme care should be taken not to damage these cells therefore no strong chemicals should be put on the area. Many types of dressings have been tried including tannic acid membranes (Fig 12) silver foil vari ous chemicals and sprays exposure etc. but they seem to heal most rapidly under fine mesh grease gauze This source of informa tion in epithelial healing is one of the most practical available There is much more in vestigation to be done with material already on hand

PINCH GRAFTS
(Small, Deep Grafts)

These grafts consist of small islands of skin of varying thickness which can be cut quite easily by anyone and transferred indi vidually to the recipient site Since they are the simplest of execution untold numbers of them have been lost or placed on unsuit able areas This is not a fault of the method per se but is perhaps due to the fact that sometimes they are used by surgeons who

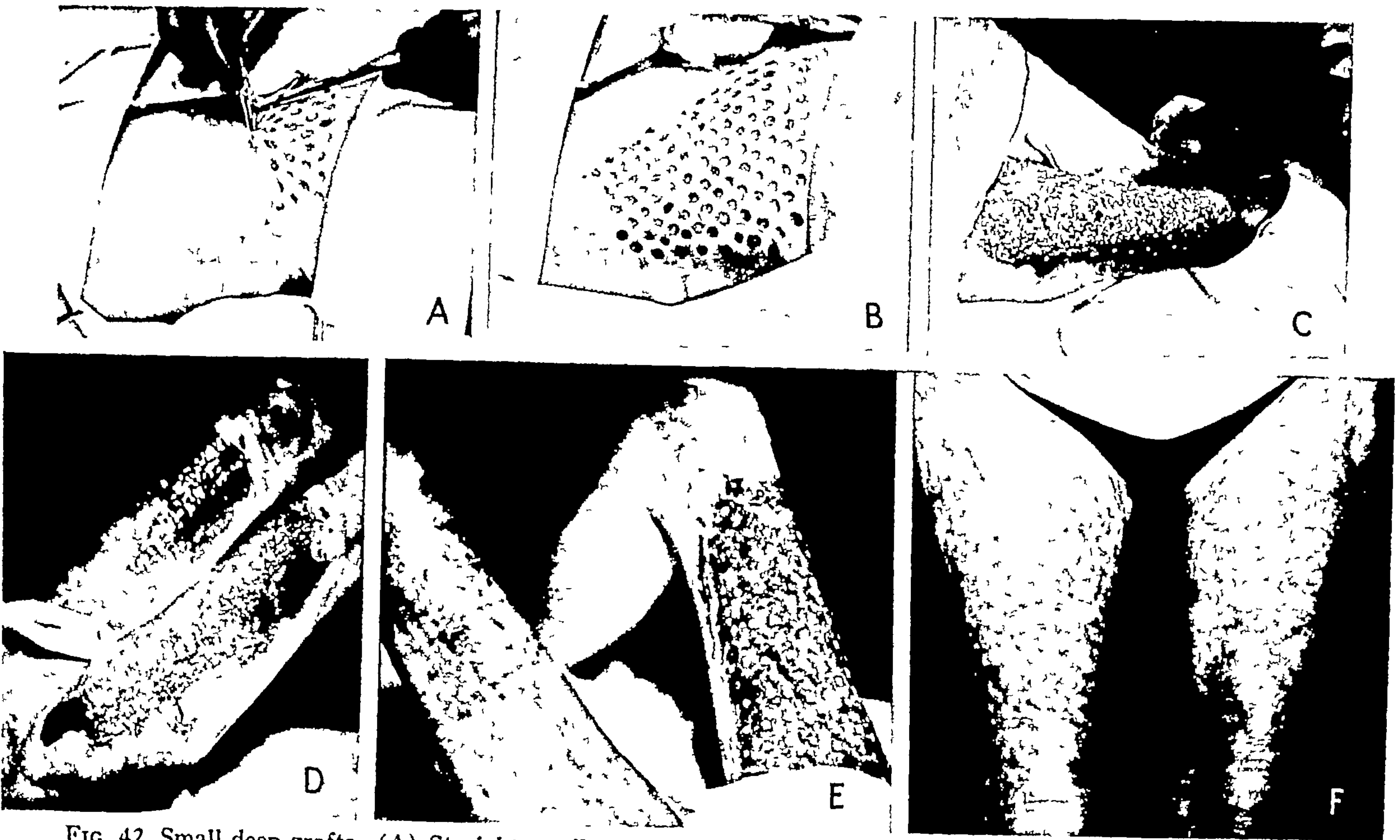


FIG 42 Small deep grafts (A) Straight needle on a clamp lifting a cone of skin which is cut off and left on the needle for transferring to the raw area (B) Donor site (C) Grafts firmly in place and the beginning of a very careful dressing with a role of fine-mesh grease gauze ready to "snub" the grafts in place (D) Very clean areas of full-thickness loss, practically the same extent on both thighs (E) Six days after the pinch-graft operation (under local anesthesia) with all grafts viable The opposite thigh in the meanwhile has been covered with thick split grafts (F) Final result 7 months later The roughness of the pinch-grafted thigh does not matter much, since it is covered, but the final bearing support of this thigh was about 5 months behind the split-grafted thigh (Internat Abst Surg 67 105-116)

are unfamiliar with the principles and the various methods of skin grafting

Reverdin originally described this graft as including little more than small bits of epidermis, but anyone using this method (as did perhaps Reverdin himself) will soon find that deeper bits of skin going quite far down in the derma will give better results. Dr J S Davis did most to popularize this type of graft and called it a 'small deep graft." The term "pinch graft" originated when they were removed by pinching up a bit of skin and cutting it off, but this method is too traumatizing and is no longer used. The present technic of application is outlined in Figure 42

The wounds are prepared for grafting in the same manner as outlined in Chapter 7, but it is thought by some that the wounds need not be as clean as for split grafting

The chief **advantages** of these grafts are that they can be taken and applied under local anesthesia with very little blood loss or other debilitation from the operation At times, they may even be applied to small wounds without taking the patient to an operating room but due care should be exercised to avoid infecting the donor sites If they fail to grow, not much has been lost (if donor areas good for other types of grafts have not been used), but if good preoperative care is given the wound there should be an excellent percentage of survival of these grafts.

The **disadvantages** of these grafts include the fact that they do not give a smooth, final surface and practically should not be used on areas not covered by clothing (Figs. 42 and 43) The healing between the small deep grafts is essentially by scar epithelium and the continued wound stimulus during this prolonged healing period is apt to result in the most contracture occurring with any type of graft, though not nearly so much as in spontaneous healing For the same reason they cannot be used very satisfactorily for covering wounds which are made by opening contractures When these grafts are used, they should not be taken from a possible suitable future donor site for split or full thickness grafts, and they should be removed from as small



FIG. 43 Appearance 8 months after coverage of extensive burns of backs of both lower extremities (elsewhere) with small deep grafts Function seemed to be good, possibly influenced by being in a region where powerful muscles oppose contracture. Appearances here does not matter much but would be bad on exposed surfaces



FIG 44 (*Left*) Ill-advised destruction of good donor areas by removal of pinch grafts (elsewhere) in a patient with extensive burns of axilla and neck Freshly healed split-graft donor site shown on inside of right thigh (*Right*) Healed split-graft donor site in another patient

an areas as possible (Fig 44) Some of the most pathetic patients are those with huge raw surfaces where someone has transferred a totally inadequate number of these grafts from widely scattered areas throughout all of the available good donor sites In general, they are of more historical interest, than of present value.

The after-care of these grafts is practically the same as for split grafts, except that healing usually takes longer The first dressing is done on the 3rd, the 4th or the 5th day, and the entire area is gently cleansed using soap and water if necessary Greased or wet fine-mesh gauze is applied with a pressure dressing outside, and then the wounds can be dressed daily or every other day, depending upon their appearance After 8 or 10 days, thin bluish scar epithelium can be seen growing from the edges of each graft, and these sheets of epithelium later coalesce to complete the closure of the wound

The donor areas are dressed in the same manner as for split grafts and usually heal in 2 or 3 weeks (Fig 44) The first dressing can be left on for 2 weeks and then changed as necessary If the grafts are all removed from a small elliptical area, it is possible to excise completely the donor site, undermine the edges and bring them together with sutures to prevent the rough "cobblestone" appearance which might otherwise follow

Sieve grafts are the exact opposite of small deep grafts in that the "pinches" are left on the donor site, and the portion that would ordinarily be the donor area is transplanted A small, circular, sharp metal die is used to cut the islands out of the piece of skin which is to be transferred. These sieve grafts have been advocated by Dougla

FULL-THICKNESS GRAFTS (Wolff-Krause Grafts)

Full-thickness grafts include the complete depth of the skin without any attached fat

(Fig 39) and were first described by George Lawson They give the nicest immediate appearance of any of the free grafts and are used for resurfacing on the face, the neck and the hands where possible (Figs 45, 215 and 327)

Clavicular grafts (from skin either above, over or just below the clavicle) remain very soft and flexible and give about the best color and texture match of any for small facial repairs They are especially desirable on eyelids and lips (cf Chaps 10 22, 23, 24)

Postauricular grafts are readily obtained for small facial repairs and provide a good color match in some patients but are apt to be too pink or red in others They are usually not as soft and flexible as clavicular grafts

Larger full thickness grafts are usually obtained from the lower abdomen the upper thigh or the inguinal area (outside the zone of hair) but may be obtained from the inside of arms or thighs or other thin skinned areas

The "take' of full thickness grafts on granulating surfaces is uncertain so that their use in burns usually is limited to re



FIG 45 (*Top left*) Deformity of neck and face from burn scar that extends from arm across the axilla and has pulled skin normally under the jaw all the way down to the clavicle (*Top right*) Correction of deformity with one full thickness graft let in low down Surface unevenness left for later correction (*Bottom*) Completed correction with full thickness grafts has been done in 2 stages to avoid injury to lower branch of 7th nerve (Surg Gynec & Obst 60 379)



FIG 46 Use of pedicle flap to restore deep loss on dorsum of the hand (*Top*) Hand on splint with elastic traction to fingernails and thumb rotated Direct abdominal flap has been raised (*Center*) Coverage with direct flap (*Bottom*) Result (Ann Surg 107 967)

placement of scars or release of contractures When they are done in a proper manner and on freshly opened wounds, the "take" is almost certain, and the result usually will be the best that it is possible to obtain However, the amount which can be transferred is strictly limited, as their use amounts to the trading of raw surfaces If the donor areas are small, often they can be closed by undermining the edges and suturing, but if they are large it may be best to cover them with split grafts Full-thickness grafts are exceedingly tedious to do, and one 4 x 5 inches is considered large. As a working rule, one should consider full-thickness grafts for all exposed surfaces and for the hand and then substitute the more simple thick split graft, if it is thought to be applicable

"Accordion grafts" are full-thickness grafts in which multiple slits have been made so that they can be stretched to cover

a larger area The former practice of stabbing multiple drainage holes in ordinary full thickness grafts has been discontinued because of the ugly resultant scars, and the same objection holds for accordion grafts.

PEDICLE FLAPS

A flap consists of a portion of skin and attached subcutaneous fat which is taken loose from the donor site except at one side or end where a pedicle is left, through which vessels course to nourish it The flap is attached to the recipient area, and the double connection to the donor and the recipient areas is left until a satisfactory blood supply is established from the latter (Fig 46) Usually 2 or 3 weeks is sufficient and then the pedicle may be cut across at once or in stages The donor area can be closed by undermining and suturing if small, or by free grafting if large (cf Chap 11)

Flaps are usually necessary only when it is desired to transfer bulk to restore contour and are neither necessary nor advisable where only resurfacing is desired They are extremely laborious and cumbersome, and patients who have heard only of them are sometimes fearful of all plastic surgery The transferred skin, in some instances may have a more normal color and texture than a free graft but the general blobbiness of the repair may turn the result into defeat (Fig 87) At times the use of the pedicle flaps cannot be avoided but many repairs which were formerly done with flaps are now being done with free grafts in a more direct manner and with better final results

9

Cutting and Application of Thick Split-Skin Grafts

If any considerable area is to be grafted, general anesthesia is used Local anesthesia can be used for smaller areas but is more difficult for both the patient and the surgeon In severely debilitated patients, a compromise may be used by cutting the grafts during a few minutes of light nitrous-oxide or Pentothal Sodium anesthesia and then wrapping them on over the granulations by the "snubbing" method with the patient awake

It is usually better to plan to cover raw areas first and to open any contractures at subsequent operations, unless the raw areas are small and the contractures great

Any granulating areas are washed thoroughly with saline under anesthesia, and then both surrounding recipient and donor skin are painted with very dilute tincture of iodine (usually under 1%), or other antiseptic of choice, and the sterile draping is done

SELECTION AND PREPARATION OF DONOR SITE

If one thigh is available, it will nearly always be the area of choice and should be draped so that the whole circumference is accessible from well up on the buttock to slightly below the knee (Fig 47) Sometimes a large adult thigh will yield nearly 200 square inches of graft by complete decortication, but if that much or more is desired, it may be wise to drape an additional donor area When both thighs are available, sufficient skin can be obtained to cover almost any defect The back is usually the next best donor area, especially in obese patients (Fig 50), but it may be difficult or impossible to cut over the iliac spines and crest and over the ribs in thin individuals Sometimes a surprising amount of skin can be obtained from both buttocks The utility of the abdominal wall varies with the nutrition of the patient, usually only scrappy grafts can be obtained from thin patients, but really worth-while ones may be secured from an obese abdomen It is almost impossible to remove decent grafts from the anterior chest wall with a knife, but suitable ones can be cut with the dermatome and other machines The upper extremities and the lower legs are practically useless except for very small grafts In general, grafts are easier to cut early after a burn, before debilitation and cachexia are present

Grafts will grow hair if they are thick enough and if they are taken from hairy donor sites This is of importance, especially if they are to be put on the face or the neck or inside the nose or the mouth, and donor areas which are as nearly hairless as possible should be selected Even on men's faces, it is usually best to use fairly hairless grafts, as the graft hairs will not simulate a beard because of their distribution, direction and texture

Donor sites should be shaved before operation for additional cleanliness and ease in cutting the grafts unless the grafts are to be used in the above areas

FREE HAND CUTTING OF GRAFTS

These grafts may be cut in several ways the main essentials being a long sharp knife and some method of producing a smooth diaphragm on which to cut

The graft knife can be of the ordinary amputation variety or one especially made for the purpose but it must be long and sharp A razor is useful only for obtaining small chips A special straight knife with a ribbed back razor-steel blade 18 cm long[1] is quite satisfactory if someone is available to sharpen it properly at frequent intervals. Essentially the same knife but with interchangeable blades (Fig 48) has been de

[1] Obtainable from R H Tontrup Co 1801 S Hanley St St. Louis, Mo

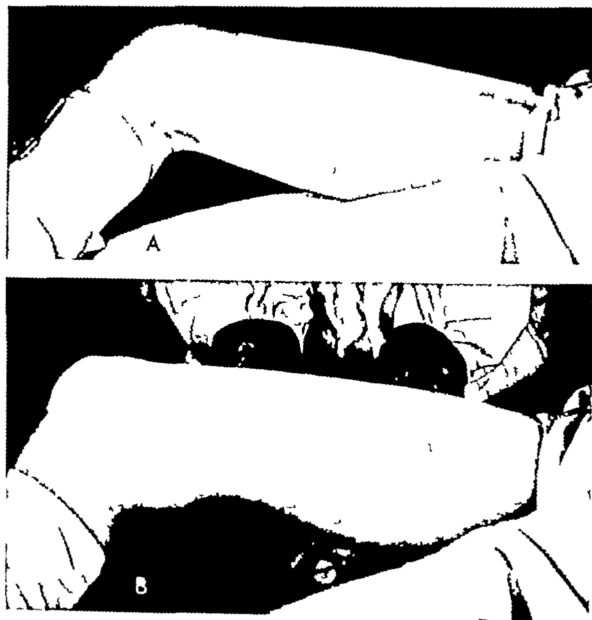


Fig 47 (*Top*) Thigh draped for use as a donor site The entire circumference from the upper buttock to below the knee is left out. (*Bottom*) An assistant can smooth out the inner surface for cutting by tightening the skin and pushing all of the soft tissues medially

signed by Ferris Smith,[2] and its use simplifies the sharpening problem Large grafts have been cut with an ordinary carving knife, but the best knife obtainable should be considered a necessity rather than a luxury The knives are not autoclaved or boiled, but are sterilized by immersion for 30 minutes in 95 per cent alcohol and then carefully dried without touching the cutting edges

The diaphragm is produced by stretching the skin and simultaneously depressing it, as with two large spatulae (Fig 37), or elevating it as with tenacula, a vacuum suction retractor, Kirschner wires, or with glue (as on the dermatome) The suction retractor[3] (Fig 49) described in 1929 is used almost routinely and seems to be the best present method of producing a diaphragm but is probably not the final answer to the problem A special explosion-proof motor, or some means of getting 25 to 28 lbs of suc-

[2] Obtainable from Weck and Co, 135 Johnson St, Brooklyn, N Y

[3] Obtainable from Storz Co, 4570 Audubon, St Louis, Mo



Fig 48 Granulations are never scraped but are sliced off smoothly with an old graft knife, razor or scalpel Care is taken to prevent contamination of the new base. Surrounding bluish scar epithelium is also usually removed.

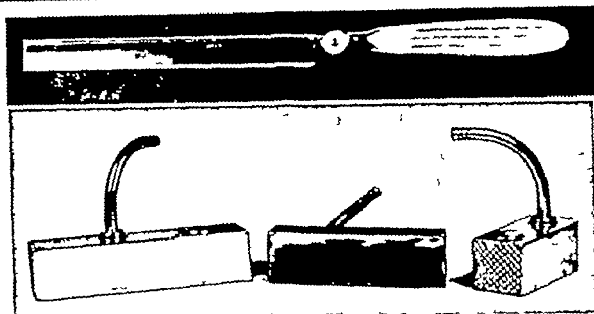


FIG 49 (*Top*) Smith Weck graft knife with an interchangeable blade of ribbed-back razor steel 18 cm long Blades can be resharpened a few times and new ones are inexpensive. (*Bottom*) Suction retractors used for creating a diaphragm of skin on which to cut These are hollow brass boxes with cross bars on the under surface to prevent the skin from being drawn up into them. They are connected by noncollapsible rubber tubing to a strong suction machine (usually 25 lbs of negative pressure) Three lengths are available 4 5, 7 0 and 9 5 cm the middle size being most generally useful The valves that were present in the old ones were a source of leakage rather than a help

tion (negative pressure) at the patient is essential Considerable ingenuity must be exercised with any method to get a flat surface and moving the leg around to relax any prominent muscles on the thigh may help The hollow which is sometimes present just in front of the gracilis muscles often can be flattened by an assistant who either grasps the soft tissues on the outside of the thigh to tighten the skin on the inside or pushes all of the soft tissues medially to fill the depression (Fig 47) Moderate flexion of the knee may reduce the prominence of the hamstrings and slight abduction of the thigh may flatten the iliotibial band when cutting in those areas Considerable difficulty may be experienced in getting over the greater trochanter or the posterior inferior iliac spine The largest thigh grafts usually can be obtained from the posterior surface extending from high on the buttock down almost to the knee (Fig 53) The inner and the lateral surfaces are quite useful (Fig 52) but the anterior surface varies according to the state of nutrition and resulting prominence of the femur In a well nourished patient the largest grafts may be obtained sometimes by starting near the scapula and coming down over the buttock and the thigh almost to the knee (Fig 50)

Cutting the Grafts. A thin film of petrolatum is first spread on the donor area The skin is picked up and stretched flat with the suction retractor while an assistant makes countertension and the graft is cut with long even strokes of the knife staying about 1 or 2 inches behind the suction retractor as it is moved along slowly (Figs 51 52 and 53) The back of the knife is often used to help create the diaphragm and it is helpful to practice cutting small grafts at times with the knife alone The suction retractor is usually held level with the skin surface but may be elevated or depressed slightly when necessary After part of a strip has been cut the loose end may fall down

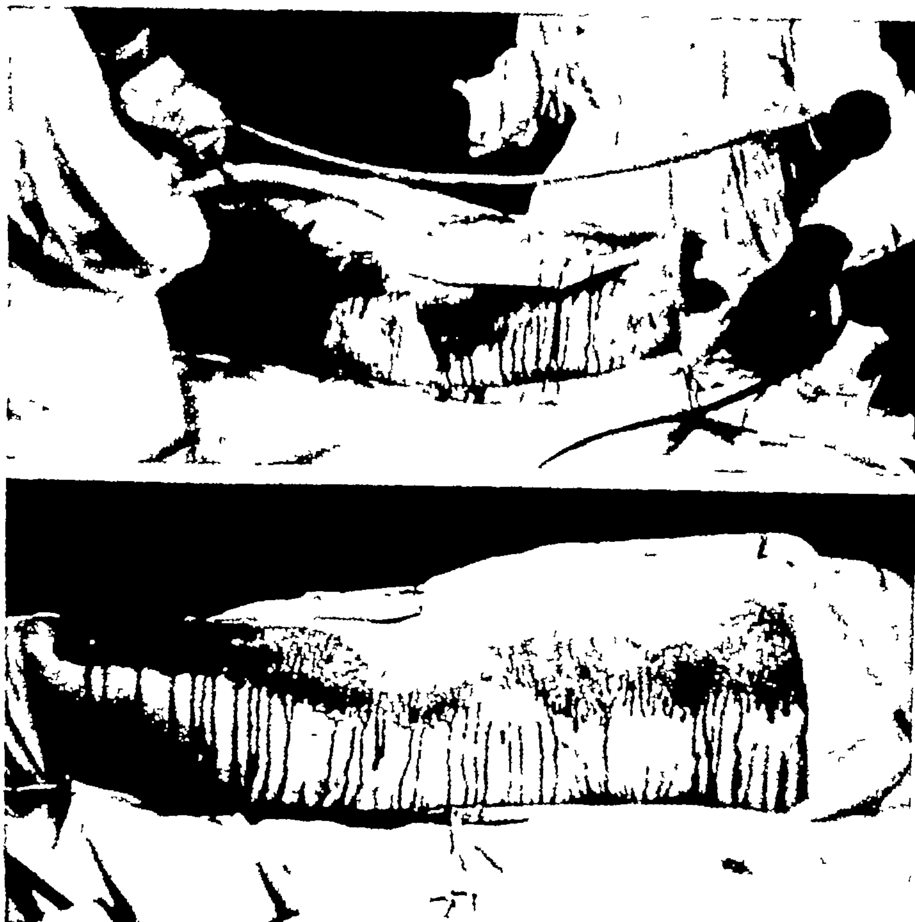


FIG. 50 Large grafts greatly facilitate extensive repairs (*Top*) One graft 36 inches long and 4 or 5 inches wide is seen, held above the patient Another one 18 inches long and 5 inches wide is lying on the patient, detached except at one end Both grafts were cut with a suction retractor and a knife (*Bottom*) Donor site of a single large thick split graft The total amount removed at this operation was 200 square inches Same patient as in Figure 151 (Ann Surg 115 664)

in the way but can be held back enough for vision by an assistant, though the graft should be allowed to ride back and forth with the knife and not be kept taut Judging depth requires a little experience, but when proper, the knife blade usually can just be seen through the graft, and the derma presents a definite resistance to cutting In general, the grafts should be cut as thick as possible but a donor site should be left without any granules of the fat showing so that it will heal rapidly When it is desired to cut multiple crops at intervals from the same donor site or when removing grafts from the thick skin of the back, it may be desirable to cut them relatively thinner. Grafts destined for the interior of the nose, the mouth or the orbit probably should be rather thin The thickness can be graduated fairly well and certain patterns can be adhered to roughly after a little practice The cutting may sound difficult, but actually it is fairly easy, and nearly all internes and residents going through the service are able to obtain good grafts after a few trials

In large repairs, the grafts should be cut as large as possible (Figs 37 and 50), as small grafts are apt to be uncertain, nerve-racking and time-consuming

HUMBY KNIFE AND VARIATIONS

From time to time, various surgeons have attached a small skin roller, or other guide, to the graft knife just in front of the cutting edge of the blade The general idea is to keep an inexperienced operator from cutting too deeply, but the contrivances do interfere with free motion of the knife and almost prevent obtaining large grafts Perhaps the first one was brought out by Humby in England, a later one by Marcks in the United States, and various others by surgeons in different countries and they have been so named



FIG 51 Technic of cutting the graft The suction retractor is moved along about 1 inch in advance of the knife while an assistant makes countertraction with a soap dish or a spatula Suction machine and tubing also shown (*Bottom*) The graft is shown spread out on the table It should be covered with moist gauze and the latter clamped down to the table cover to prevent loss. (Surg Gynec. & Obst 60 379)

THE PADGETT HOOD DERMATOME[4]

The Padgett Hood dermatome may be of use in obtaining grafts up to 8 by 4 inches from the backs of children or undernourished adults or from the thoracic wall (Fig 54) The knife blade should be set as close to the drum as possible unless one is very familiar with the instrument which he is using as the general tendency is to cut too deep Any attempt at "calibration" of the thickness of a graft in millimeters or other fixed units does not seem particularly usable to us as the thickness of the skin varies with race age state of nutrition, from one individual to another and from one region of the body to another The thickness of a graft cut with the dermatome may even vary according to the amount of tension used so that one graft may be of different thicknesses in various parts This is also true if there is any play in the knife arm, or if the two ends of the blade are not set at exactly the same distance from the drum. However it is an ingenious instrument and may be a

[4] Obtainable from Kansas City Assemblage Co 816 Locust St., Kansas City Mo

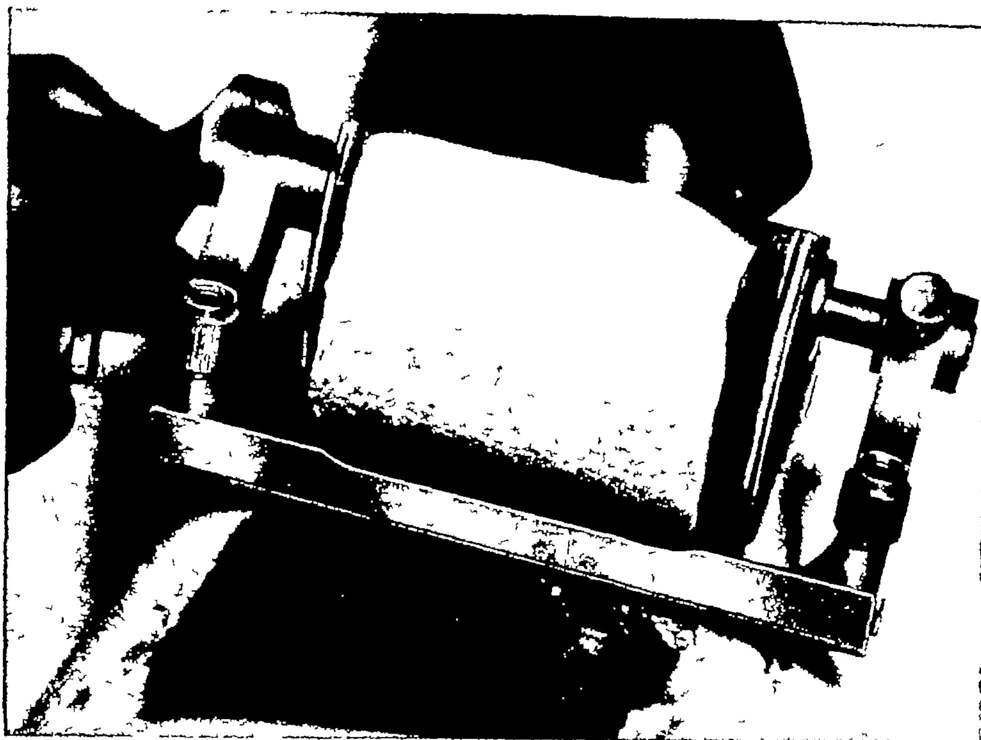


FIG 56 Reese Dermatome, for cutting split skin grafts See text, and manufacturer's instructions for method of use (Bard-Parker Co)

thin but black and is painted on the drum, using a small sponge folded in the tip of a Kelly clamp for a paintbrush Rubber cement is poured in a separate medicine glass, diluted with a small amount of ether and then applied to the skin The cements are allowed to dry for 2 or 3 minutes, then the drum is pressed on the skin, and the graft is cut as usual The two cements give better adhesion for the graft cutting than the rubber cement alone After cutting, the graft is peeled from the drum quickly and easily with no cement on its surface The drum is cleaned by scrubbing it with ether

In the past, various workers have used sheets of pliofilm and other materials between the drum and the graft, have applied various powders to the outer surface of the graft during or after removal, and have tried numerous other maneuvers to keep the graft from wadding up into a useless mass The two cements described above are a quick and easy solution to this major annoyance

THE REESE DERMATOME[6]

The Reese dermatome is a metal-drum type, with a dermatape which is applied to the outside of the drum and adheres to the skin After cutting a split graft, the tape and the attached graft are peeled from the drum and applied to the recipient area At times, this can be done in such a manner that the overlapped edges of tape will adhere to the skin margins adjacent to the defect, thus fixing the graft in place Dr Reese and his associates spent a great amount of time in studying the mechanical principles involved, as well as various metal expansion coefficients, etc , in order to make this a precision instrument Practically everyone who uses it agrees that they have accomplished this purpose and have developed an excellent instrument for cutting uniform split grafts (Fig 56)

THE BROWN ELECTRO-DERMATOME[7]

The Brown electro-dermatome was conceived by Dr Harry M Brown of Indianapolis while a prisoner in the Philippines during World War II It is a cable-driven machine with a blade that cuts 8,000 strokes per minute. The head is constructed

[6] Obtainable from Bard-Parker Co , Danbury, Conn

[7] Obtainable from Zimmer Mfg Co

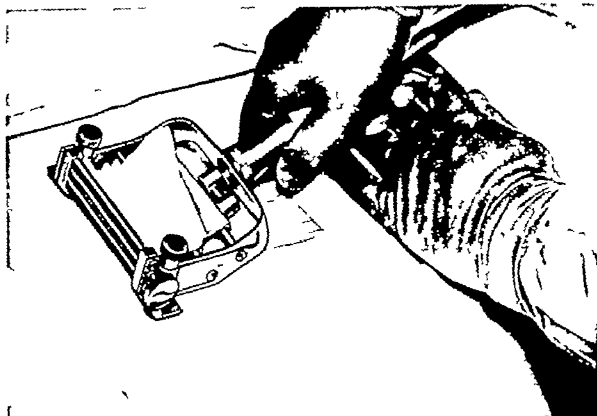


Fig 57 Brown Electro-Dermatome for cutting split skin grafts See text. (Zimmer Mfg Co)

so that the blade will be kept at a predetermined distance under the surface of the skin and no cement or suction is used It will cut grafts up to 3 inches in width the length being determined by the available flat donor area The newer explosion-proof model has the very great advantage that it it is designed to use safely in the presence of flammable general anesthetics (Fig 57)

In addition to other uses this instrument has been used extensively on our service for cutting very long strips of postmortem homografts

THE PADGETT HOOD ELECTRO DERMATOME[8]

The Padgett Hood electro-dermatome has the motor in the handle and is designed to cut grafts up to 4 inches in width and as long as the available flat donor area (Fig 58)

[8] Obtainable from Kansas City Assemblage Co 516 Locust Kansas City Mo

THE BARKER VACUTOME[9]

The Barker vacutome consists of a suction box with an attached knife arm so that the blade can be adjusted at a desirable distance under the surface of the suction box The skin is first coated with petrolatum as in the free hand cutting of

[9] Obtainable from Johnson Mfg. Co Chippewa Falls Wis.

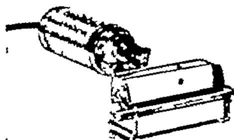


Fig 58 Padgett Hood Electric Dermatome for cutting split skin grafts See text (Kansas City Assemblage Co)

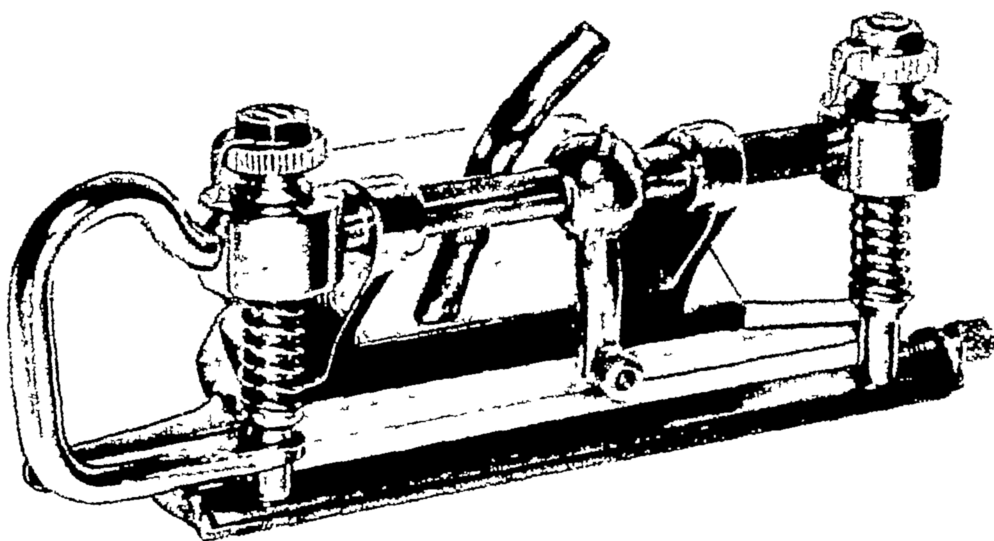


FIG 59 Barker Vacutome, for cutting split-skin grafts See text (Johnson Mfg Co.)

grafts, and the suction box is moved along to create a diaphragm in much the same manner The fixed distance of the knife is designed to procure a uniform thickness of graft and, if properly set, to avoid cutting the graft either too thin or too deep The instrument is designed to cut split grafts up to 4 inches in width and as long as the available flat donor area (Fig 59)

GENERAL CONSIDERATIONS OF GRAFT-CUTTING MACHINES[10]

There are, and will be, other graft-cutting machines available, and the omission of their description, or the length of the description of these, is in no way intended to reflect their relative merit Various operators will prefer one over the other, at least for certain purposes, and each surgeon will learn his preferences by actual experience It is probable that none has reached the acme of perfection, but that all will do a reasonably good job if used carefully according to instructions, by a surgeon who has some knowledge and experience in split-skin grafting

Notwithstanding some of the propaganda, the purchase of one of these machines will not make an untrained surgeon an expert in the art of skin grafting overnight It would be as reasonable to suppose that the purchase of a 3-bladed clamp would make any surgeon an expert in gastro-intestinal resections

Cutting the graft is probably the least difficult and requires the least judgment and knowledge of any of the facets of skin grafting More difficult phases include deciding what patients require grafting, when to do the work how to prepare the wound, fixation of the graft, getting the donor area to heal, and getting the graft to take, plus the handling of all possible complications

Any surgeon who has reasonable control of his hands and is willing to study the subject sufficiently to learn the elements of the above can learn to cut grafts "free-hand" with only a little effort This effort will be well rewarded, as it will free him from any dependency on particular machines, and will carry him toward being able to cope with any grafting situation at any time

They all cut with a knife and provide some sort of diaphragm of skin at a fixed distance With experience, the surgeon will learn that skin diaphragms can be created in various areas on different patients in certain ways that are the best in each instance He will learn to think of depth in terms of percentage of thickness of the skin in that area on that patient and will guide his knife so that he will get thicker graft

[10] Some of these machines have been reproduced in foreign countries under other surgeons' names

from thicker areas and thinner graft from thinner areas even while cutting one long strip He will learn to cut roughly to pattern He will find that he can cut all of the graft that he wants for any patient in 10 or 15 minutes Being independent of any machine he will learn which one can be most useful to him in any particular situation

Some of the most pathetic patients have been those who originally had moderate areas of deep burn but come in with those raw and with huge, raw infected donor areas These have been the result of surgeons who knew little or nothing about skin grafting buying a machine with the idea that cutting a graft is all that is necessary Such instances have been the worst in those with thin skin including emaciated adults and very young children who are least able to tolerate this denudation

The above remarks are not directed against the machines which are very useful instruments, but are meant to point up that they should be used only by those who know what they are about

SLICING OFF GRANULATIONS

In grafting any granulating wound the question always comes up whether to apply the graft on top of the granulations or first to excise the granulations and apply the graft on the underlying firm yellow bed

In general the graft is apt to take more completely if the granulations are first excised so this procedure is usually carried out with small and medium-sized wounds In large wounds however the blood loss from this excision may be too great (especially in debilitated patients) so that it is usually omitted and the grafts are simply applied on top of the granulations

If the granulations are to be excised they are usually sliced off in a sheet with an old graft knife (Fig 48) taking care to avoid undue contamination of the underlying yellow bed and also being careful to avoid injury to any important underlying structures For smaller wounds a straight razor or scalpel can be used In either event usually it is best to remove the surrounding bluish scar epithelium at the same time out to normal skin

Hemostasis is secured mainly by pressure with warm saline gauze sponges or occasionally with such sponges wrung out of 1 5 000 adrenalin solution Extremities can be wrapped snugly with gauze rolls to secure circular pressure for a few minutes Most oozing can be controlled by persistent efforts in this direction Small spurting vessels or visible venules may be ligated with No 000 white silk cut on the knot catgut or other larger ligature material is not used under free grafts Heat or diathermy coagulation of vessels is not used In general it is not good practice to apply grafts while a tourniquet is on the extremity

Grafts seem to have some hemostatic properties in themselves but in general the field should be fairly dry before they are applied The two main causes of loss of grafts are infection and hematoma and of these hematoma is probably the more common

APPLICATION OF GRAFTS AND FIXATION

Before applying the graft the recipient area should pass a final inspection The contour is noted and any irregularities are trimmed down smooth when indicated Edges of the defect generally should be sharp smooth and within good skin The bed is especially inspected for adequacy of minute blood supply in every square centimeter If necessary deeper excision is done or adjacent vascular tissue may be sutured over ischemic areas with interrupted No 000 white silk Any small troughs or depressions can be closed in the same manner The recipient area should be as smooth as possible with an adequacy of small blood vessels in every part but with oozing and bleeding controlled

The grafts are now laid on the recipient area moistened with a little saline and then

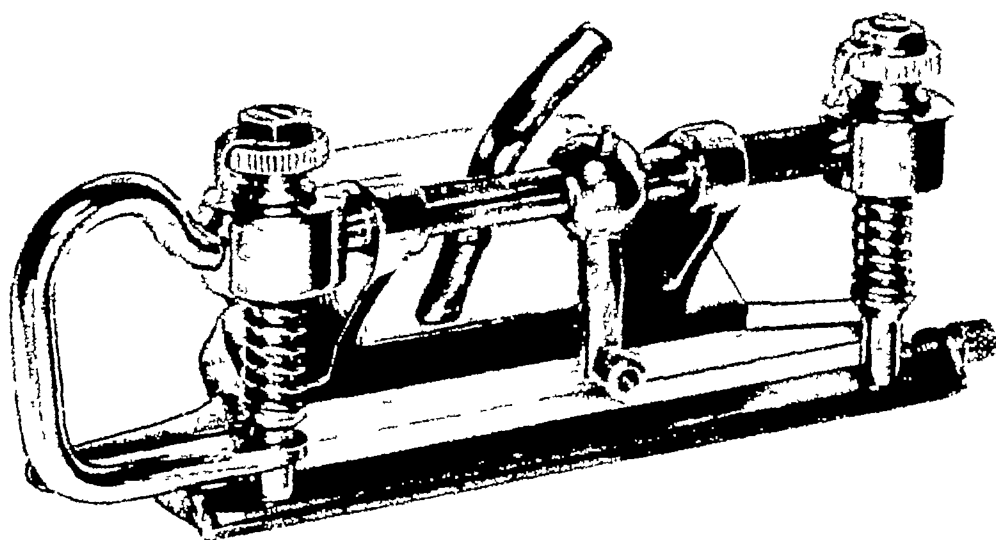


Fig 59. Barker Vacutome, for cutting split-skin grafts See text (Johnson Mfg Co)

grafts, and the suction box is moved along to create a diaphragm in much the same manner The fixed distance of the knife is designed to procure a uniform thickness of graft and if properly set, to avoid cutting the graft either too thin or too deep The instrument is designed to cut split grafts up to 4 inches in width and as long as the available flat donor area (Fig 59)

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They all cut with a knife and provide some sort of diaphragm of skin at a fixed distance With experience, the surgeon will learn that skin diaphragms can be created in various areas on different patients in certain ways that are the best in each instance He will learn to think of depth in terms of percentage of thickness of the skin in that area on that patient and will guide his knife so that he will get thicker graft

[10] Some of these machines have been reproduced in foreign countries under other surgeons' names

smoothed out flat by brushing them with the fingers or the back of a forceps Ordinarily, they should be allowed to overlap the normal skin edges and each other for about 1 cm all around, but if the defects are huge and donor sites limited, occasionally it may be necessary to "space" the grafts so that they do not quite touch each other or the skin edges

SUTURE FIXATION

The sutures used are No 000 black silk on half or quarter curved cutting needles of ⅜ to ¼ inch size Each graft is first fixed with a running stitch which goes through the graft, through the skin edge and then out through the graft, all around the edge The grafts are sewed on at about skin tension so that they will not have any wrinkles or yet be very tight

A basting stitch can also be run up and down the central portions for further immobilization, if desired (Figs 60 and 61), but will leave marks

Drainage holes were formerly stabbed in the grafts throughout, but they leave unsightly scars and do not drain blood unless they are right over a bleeding point, now they are usually omitted Blood must not be allowed to collect and clot underneath the grafts during the suturing It is removed by brushing the graft rather firmly toward the periphery with a blunt instrument at intervals and again just before the dressing



Fig 60. Coverage of defect shown in Figure 18 with two grafts Basting sutures shown. Wound covered in one operation, after patient had gone through last four months of pregnancy with it, at home in rural area

is applied Occasionally, it may also be necessary to irrigate underneath the graft with saline from a syringe

SNUBBING ON GRAFTS

The term "snubbing might be explained as binding on grafts with roller bandages without suturing

On many flat areas suturing is omitted and the grafts are snubbed on with a roller bandage of fine mesh grease gauze This is used particularly on the flat surfaces of extremities In grafting large raw burns The grafts are smoothed out carefully in place brushing them with a flat instrument to remove all underlying air blood or serum The greased bandage is then rolled on steadily and snugly in the direction that it wants to go without twisting it varying the tension or other maneuvers that would slide the grafts The usual pressure bandage and splinting are applied external to this

Numerous autogenous homogenous and heterogenous extracts have been described as "glues for this work but none of them seems to be necessary or particularly helpful



Fig 61 Neck contracture opened with very thick split grafts and sutures shown The graft overlaps the edges of the wound slightly A nasal feeding tube was used to minimize movements of the larynx under the graft.

TIE-OVER DRESSINGS

In areas where there is motion and irregular contour the edge sutures of the graft are interrupted and left long to be tied over a pad of surgical waste for internal fixation of the graft After the sutures are all in and ready a sheet of fine mesh grease gauze is put over the graft then the pad of waste and the sutures are tied-over In a few instances one will want to pull the graft around the pad of waste so that the latter will be small In most instances however the pad of waste will be so large that even when it is compressed it will overlap the graft this gives the effect of tying the pad down on the graft for pressure and keeps the graft flat The usual external pressure dressing and splints when necessary may be applied outside of the tie-over dressing

Stent fixation is a term sometimes used for these tie-over dressings. 'Stent" was a brand of Dutch dental wax, but this type of wax is now seldom used except inside the mouth and sometimes in the anophthalmic orbit or in the vagina

The Pressure Dressing on the Grafts

The dressing should be regarded as part of the operation and probably has more to do with the take" of the grafts than any other step except possibly the preparation of the wounds (Figs 62 to 65) On extensive areas its application may require up to 30 minutes Pressure is relied on for asepsis by preventing collections of blood or serum underneath the graft and by minimizing

edema in the area Its application should be purposeful and uniform, and considerable ingenuity may be required to get it in certain places

Fine-mesh gauze is used for the first layer or two next to the grafts whether wet or grease dressings are to be used On extremities the gauze may often be wrapped on firmly from a roller bandage Then a layer of ordinary gauze flats is laid on smoothly, and surgical waste is applied over this The waste should be well "fluffed out" and individual portions of it tucked down into any crevices or depressions

Gauze rolls (Fig. 35) are wrapped firmly over the waste and in turn are snubbed on with ordinary bandage and rolls of 1-inch adhesive. The saving of adhesive in these dressings is false economy, and it should be wrapped spirally around up and down and used to attach the dressing to the skin above and below

Elastoplast can be used in place of, or underneath the gauze rolls in certain locations It is particularly useful for fixation of dressings on the abdominal or chest walls, or about the face

Plaster casts are seldom necessary and

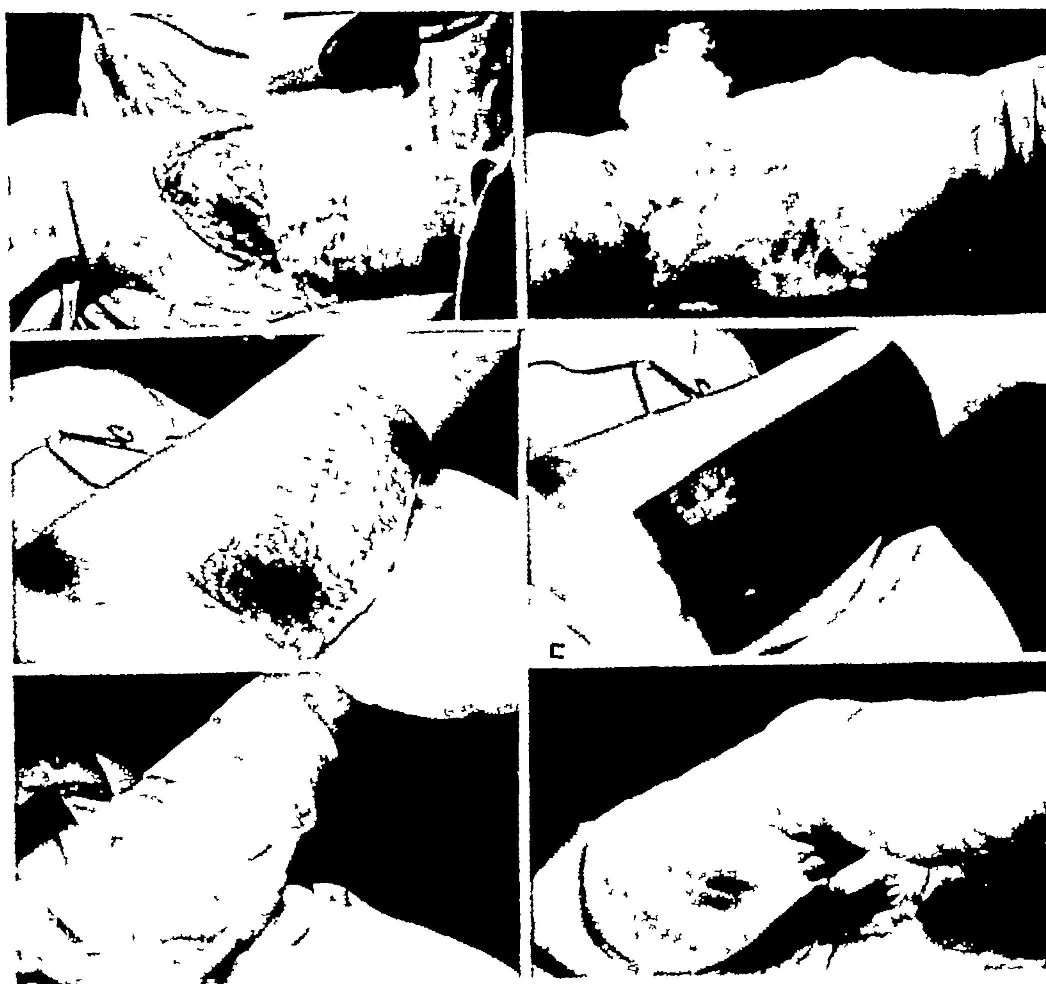


FIG 62 Dressing of leg graft and donor area on same thigh (*Top, left*) Split graft sewed on and then fine-mesh grease roll wrapped snugly around it. (*Top, right*) Waste applied over this and wrapped on with gauze roll. (*Center, left*) Donor site with a thin layer of intact derma left (*Center, right*) Double thickness of fine-mesh scarlet red gauze just over the defect (*Bottom, left*) Donor site carefully protected from mechanical, bacterial and chemical trauma (*Bottom, right*) Whole leg with firm pressure dressing (Ann Surg 115 668)



Fig 63 (*Top*) Grafts on both thighs with no sutures but 'snubbed' on by wrapping with a roll of fine-mesh gauze A thick gauze roll is being wrapped on outside this. (*Bottom*) All grafts and donor areas (back) incorporated in large secure dressing Dressing is laborious but necessary and is an essential part of the operation (Ann Surg 115 661)

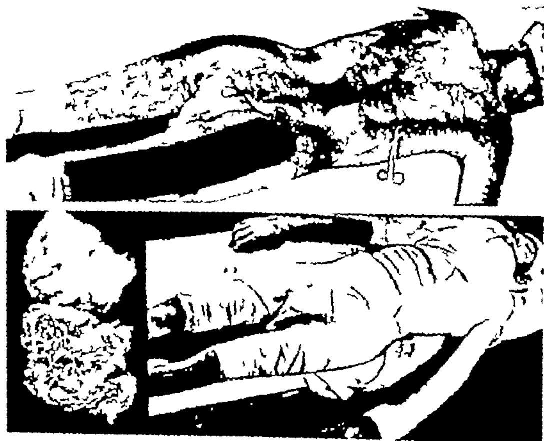


Fig 64 (*Top*) Back and left arm grafted. Grafts sewed on and scarlet red gauze in place over one donor area In extensive cases, it may be necessary to prepare almost the entire skin of the body and leave it accessible when draping Patient receiving intratracheal anesthetic

Fig 65 (*Bottom*) Same patient Final massive dressing 210 sq in of grafting done Surgical waste is shown at left. (Ann. Surg. 115 1174)

are used infrequently Hip and shoulder spicas are apt to slip when put on outside a bulky dressing A very light posterior or anterior plaster splint is sometimes included in the outer layers of the dressing when grafts are put about the elbow or the knee The impression has been gained that commercial plaster sometimes contains *Bacillus pyocyaneus*, though this may be erroneous

Wet dressings can be used if the wound was originally quite dirty and refractory to treatment before operation, or if there are any reasons to fear a degree of infection that might damage the graft Irrigation tubes can be incorporated in the dressing for the frequent introduction of saline as the inner layers should be kept constantly damp, if it is to be used In these instances it may be helpful to "waterproof" the surrounding skin with a silicone ointment, to prevent maceration

Grease dressings are used almost always, however, and just enough of the ointment should be on the fine-mesh gauze to prevent sticking, but not enough to cause maceration Xeroform ointment is the one most frequently used As more attention is paid to the preoperative preparation, the necessity for wet dressings decreases

EXPOSURE TREATMENT OF GRAFTS

pletely should be nearly 100 and is definitely much higher when good pressure dressings are used. The latter protect the graft from external factors and the pressure is important in preventing accumulations of serum or blood under the graft The pressure also does much to press the graft right down into firm, uniform contact with the endothelial buds which are invading it for nourishment.

The pressure dressings also permit immobilization of the graft and underlying area without immobilizing the patient Some trying situations have been seen of extensive traction apparatus, crucifix splints and overlying bird cages—all for small grafts where the patient could have been ambulatory, or at least could have rolled around in bed, if he had had a good dressing instead

Other types of unreliable fixation and pressure have been used, such as sandbags, hot-water bottles filled with mercury, compressed air jackets, etc

The results and the advantages of good pressure dressings are so fine that every surgeon doing this type of work should learn how to apply them

DRESSING OF DONOR AREA

Every precaution is taken to protect the sterility of the donor area Fresh instru-



FIG 66 (*Left*) Comparison of final healing in split-graft donor areas on thighs. The right leg scars are due to cutting grafts too deep These donor sites themselves had to be grafted. The left thigh has been completely decorticated all around from the knee to the groin and has healed perfectly because the derma was not cut through—and because a careful dressing was applied (*Right*) Final appearance of split-graft donor area in another patient. Growth of hair is normal.

prevent slipping and a large firm bulky dressing is securely wrapped on outside of this and anchored with adhesive (Fig 62)

The first dressing is usually the last one and it can be left in place until the donor site is completely healed and stable enough to require no further protection If the grafts were fairly thin the dressing can be removed on the 10th day but with the usual thick grafts it may be best to leave it on until the 12th or the 14th day Then it can be removed and cold cream and talcum powder applied daily for about a week (Fig 66)

If there have been any small areas of infection it will be necessary to keep small grease-gauze dressings over them until healing has taken place Massive donor-site infections are exceedingly rare but are one of the worst complications and such areas may require from 6 to 10 weeks for healing They usually result from poor dressings which slip with resultant early exposure of the wounds and the long period of healing probably is the result of destruction of much of the deep epithelium This is somewhat comparable with the processes occurring under an infected membrane on a superficial burn

The dressing may become messy from the oozing of serum and it is safe to change the outer portions of it but any early disturbance of the layers next to the wound may delay healing

If one inadvertently goes through into the fat while cutting a graft, the cutting should be stopped and the area closed with sutures

SUBSEQUENT DRESSINGS OF GRAFTS

The first dressing of a graft which has been placed on a granulating wound is usually on the 5th day though it may be best to do it on the 3rd or the 4th day if there is any question of the cleanliness Grafts which have been placed on a freshly created raw surface as in opening a contracture may go as long as from 6 to 8 days before the first dressing if one is satisfied with the cleanliness of the area Any tiny infections developing underneath the graft may spread and tend to dissect it away from the surface if the first dressing is delayed too long

The inner layer of the dressing is removed slowly and separated carefully from the graft All sutures are removed and excess edges are trimmed away The "take" is indi

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EXPOSURE TREATMENT OF GRAFTS

Many grafts will take moderately well with no dressing whatsoever This treatment of grafts is the oldest one and crops up recurrently There is hardly a plastic surgeon of great experience who has not tried this at some time and given it up, it was abandoned on our service over 30 years ago

The idea comes up generally when the surgeon is having a difficult time in applying secure pressure dressings which do not slip, rub and file on the graft The application of a good dressing to various areas is an art which does not occur automatically, but anyone can learn it

The percentage of grafts which take completely should be nearly 100 and is definitely much higher when good pressure dressings are used The latter protect the graft from external factors, and the pressure is important in preventing accumulations of serum or blood under the graft The pressure also does much to press the graft right down into firm, uniform, contact with the endothelial buds which are invading it for nourishment

The pressure dressings also permit immobilization of the graft and underlying area, without immobilizing the patient Some trying situations have been seen of extensive traction apparatus, crucifix splints and overlying bird cages—all for small grafts, where the patient could have been ambulatory, or at least could have rolled around in bed, if he had had a good dressing instead

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The results and the advantages of good pressure dressings are so fine that every surgeon doing this type of work should learn how to apply them

DRESSING OF DONOR AREA

Every precaution is taken to protect the sterility of the donor area Fresh instruments are used, and the dressings are kept separate from the materials used on the graft The immediate covering of the donor area is usually with two layers of fine-mesh gauze containing 5 per cent scarlet-red ointment This ointment is about the most drying and least macerating of any, provides a visible red tag for donor sites for anyone cutting down through the dressing and usually is highly satisfactory However, an occasional patient is allergic to it, and if there is a history of skin allergies, 4 per cent Xeroform may be used instead Over the grease gauze, a layer of gauze flats is placed These are fastened firmly to the surrounding skin with adhesive tape to



FIG 66 (*Left*) Comparison of final healing in split-graft donor areas on thighs. The right leg scars are due to cutting grafts too deep These donor sites themselves had to be grafted The left thigh has been completely decorticated all around from the knee to the groin and has healed perfectly because the derma was not cut through—and because a careful dressing was applied. (*Right*) Final appearance of split-graft donor area in another patient. Growth of hair is normal

prevent slipping and a large firm, bulky dressing is securely wrapped on outside of this and anchored with adhesive (Fig 62)

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The inner layer of the dressing is removed slowly and separated carefully from the graft All sutures are removed and excess edges are trimmed away The "take" is indi

cated by lack of any drainage, firm adherence to the wound and the pink color of the graft Any areas of "loss" are usually moist or blistered and either darker or quite white

If the "take" is complete or nearly so and the graft is clean, the same type of dressing may be reapplied and changed as necessary Subsequent dressings are done usually at intervals of 2 or 3 days, though some large contractures have been opened and grafted with only 2 dressings being necessary after the operation When the "take" is perfect, the dressing can be left off in from 10 to 12 days if it is in an area not subject to much movement or trauma but may require protection a little longer in some locations

When scattered areas of loss or infection are present, more cleansing may be needed Blebs are trimmed away, hematomata are opened, and any loose portions of the graft are trimmed out If a small hematoma is present, it may be best to incise over it, express it and apply a pressure dressing back over the overhanging edges of graft, as the latter may persist If the graft is very messy, all of it may be washed gently with soap and water even as early as the 5th day Ten per cent Mercurochrome or some other antiseptic may be used for any *Bacillus pyocyaneus* present A wet pressure dressing is applied and changed daily with cleansing until the graft is clean enough for grease dressings A split graft usually will start to send epithelium out over any defects in about 10 days, and the dressing is left off after healing has been complete for a short while

Cold cream or some other lubricant is applied once or twice daily to the grafts after the dressings are removed and until the sebaceous glands are functioning When the glands first start secreting, they may be plugged, and small "whiteheads" sometimes appear throughout the graft These are most often seen about the 3rd or 4th week and are opened with a stab blade and the contents expressed, after which there is usually no further trouble During this period the grafts may become thickened, and considerable contraction may appear, presumably as a reaction to the sebum, but they usually soften and stretch out later

10

Cutting and Application of Free Full-Thickness Grafts

A free full thickness graft includes the full thickness of the skin down to the subcutaneous tissue (Fig 38) Despite statements to the contrary these grafts still have a definite place in the repair of skin defects They have the best early appearance of any of the free grafts seem to stop the wound healing stimulus sooner and have less late contracture under them Their color may be counted on to be more uniform but if there has been any epithelial or full thickness loss (as there is apt to be) permanent scars may appear within the grafts The late appearance of these grafts in general may be said to be the best but often they cannot be distinguished from very thick split grafts after several months

INDICATIONS FOR USE

Their use is generally indicated in repairs that are not too extensive about the face the neck and the hands Their "take" on granulating surfaces is uncertain so that any open wounds in these areas are usually first covered with split grafts Sometimes the final appearance will be about as good as with full thickness grafts but if it is not the thicker grafts can be substituted later Full thickness grafts are often used for the replacement of scars or the opening of contractures in these areas.

It is not known exactly why the slight difference in the thickness of these and split grafts should cause a difference in the amount of late contracture occurring beneath them (it is of course the bases which contract and not the grafts) Presumably the cut ends of hair follicles and glands on the under surface of split grafts may cause some irritation and consequent wound stimulus until the deep epithelial growth from them has closed them beneath

This contracture factor may be an important one in deciding which type of graft to use Over a smooth bony surface such as the forehead or the scalp very little contracture is possible, and split grafts usually will give an excellent result On loose tissues however such as the cheeks or the lips or on any fat base full thickness grafts may be advisable The muscle power in the area is also a factor in preventing or stretching out any such contractures Around the axilla the elbow or the knee split grafts are used routinely Due to the powerful flexor muscles split grafts may not become contracted when put on the dorsum of the fingers but the extensor muscles are so weak that full thickness grafts are preferable on the palmar surfaces

SUITABLE DONOR AREAS

As the skin of the body varies in thickness texture and color selection of a donor site is of considerable importance The nicest thinnest skin to be found in any quantity is in the inguinal region the adjacent lower abdomen and the inside of the



FIG 67 Moderate contracture of neck with dense, corrugated scar from ear to ear Sometimes this can be corrected with only one large full-thickness graft, though the usual more severe types of contractures require 2 or 3 operations Dashes indicate line of scar excision

thigh Portions that are relatively hairless and free of striae or other blemishes are selected Sometimes smaller pieces can be obtained from the inside of the arms, or other locations The use of very thick-skinned areas, such as the back, should be avoided, as the resulting grafts may be too thick to take. The use of eyelid skin has been recommended, but it is usually not possible to get enough skin from this area for even the smallest repairs, and cutting and scarring of this flexible area has too many disadvantages for the small amount of skin obtained Scraps of foreskin from circumcision do not seem to be worthwhile, and the proposed use of scraps of skin from the labia minora is mentioned only to caution against its use

POSTAURICULAR SKIN GRAFTS

Small pieces of good skin can be obtained from behind the ears, and the donor site closed with no visible deformity. These are sometimes very useful for small facial repairs in patients with ruddy complexions but may prove to be too red in color in patients with very light or fair faces. The skin is very thin and may not resist contracture as much or be as flexible as grafts that are a little thicker

CLAVICULAR SKIN GRAFTS

Somewhat larger grafts may be obtained from the clavicular area, and these often provide the best match in color and texture for small facial repairs These grafts are also quite soft and flexible and are often

Fig 68 Reconstruction of eyelid with free full-thickness graft from supraclavicular area for best color match and soft flexibility (*Top*) Upper lid skin lost from windshield cuts and patient wearing moist chamber constantly to try and save eye (*Bottom*) Appearance and function after one operation to graft in the eyelid and one operation to trim and smooth medial and lateral edges of trapdoor forehead flap



best suited for eyelid and other repairs where this quality is important Clavicular grafts are a little thicker than those from some other areas and that quality may be important in avoiding depressions on the surface of the nose and other locations. The pink or red color tones which are characteristic of the face usually are found only in the face and the neck grafts from the body or extremities may appear much too white in this environment but clavicular grafts usually blend in nicely

These grafts are obtained from the lower neck or the upper chest adjacent to or over the medial portion of the clavicle The defect is closed by undermining and suturing in layers to provide a straight line transverse closure The resulting scar is usually just a fine line but may be noticeable particularly in women and the disadvantages of it must be compared with the advantages of this particular graft in each patient, before making a final decision. The advantages often exceed the disadvantage of the scar even in women (Figs 68, 181 and 182)

PREPARATION OF THE RECIPIENT AREA

After a contracted defect (Fig 67) is opened by dissection to the desired limit, the bleeders are tied with No 000 white silk and pressure is applied by an assistant while the graft is being cut to obtain as dry a field as possible It is important to have the edges of the defect firm for fixation



FIG 69 After removal of the contracted keloid and re-establishment of the normal neck angle, the resultant wound may be several times the size of the scar (extra fat may be laid down beneath these old scars, and removal of some of it may be necessary to get a definitive neck angle) A lead foil pattern is made of the defect, using two pieces if necessary to conform to the contour of the wound (Celluloid is easier to use than lead)

of the graft, and if any adjacent flaps have been raised, the edges should be fastened down securely with multiple deep fine white silk sutures Occasionally, it may be desirable to reef the edges back or fix them with deep mattress sutures

An accurate pattern of the defect is cut in bleached x-ray film, ½ mm sheet lead (Fig 69), or any suitable material The pattern is made the same size as the defect as a matter of record and then if it is thought that the donor skin is too tense, as in a well-nourished baby or fat women, a suitable excess may be allowed all around, for example, 1 cm larger, if this proves to be too much, it can be removed when the graft is sewed in place The main point is to have the final tension of the graft correct, as will be mentioned later

CUTTING THE GRAFT

The pattern is outlined on the donor area with 5 per cent methylene blue or other suitable marking material A small mechanical drawing pen is a useful instrument for scratching in these lines An incision is then



Fig 70 Cutting a full thickness graft from the abdomen. Assistants provide counter traction in 3 directions to keep the bed taut. The operator holds the graft in his left hand and cuts the graft loose with a knife The plane of dissection is in the very fine white fibers which attach the skin to the subcutaneous tissues (fibers have been magnified in the drawing for illustrative purposes)

made clear around the outline going just through the skin but not into the fat

The greatest help in removing the graft is to have two assistants stretch the skin in every direction into a taut drumhead this tension should be maintained throughout the cutting process A sharp scalpel is a necessity so that new knife blades are used and changed as often as is necessary during the removal of the graft. The edge of the skin can be picked up with a fine thumb forceps to start the removal of the graft but as soon as 2 or 3 cm are loose it can be held with a piece of gauze in the fingers to eliminate forcep marks as much as possible If the donor area is kept taut and the end of the graft is pulled up tightly the layer of fine white vertical fibers attaching the skin to the subcutaneous tissue can be seen readily (Fig 70) This is the plane for dissection and the fibers are gently divided a few at a time to remove the graft. The best means to prevent cutting holes in the graft is to visualize this plane constantly and not to use force enough with the knife blade to go through the graft There should be little or no bleeding but it is important to prevent any blood staining of this plane, so that a fresh sponge is used each time wiping from the graft down on to the base.

Multiple forceps or individual sutures may be put around the edge of the graft as it is being dissected if desired but usually are not necessary and may leave marks With care the graft can be removed without taking up any fat and it is thought that

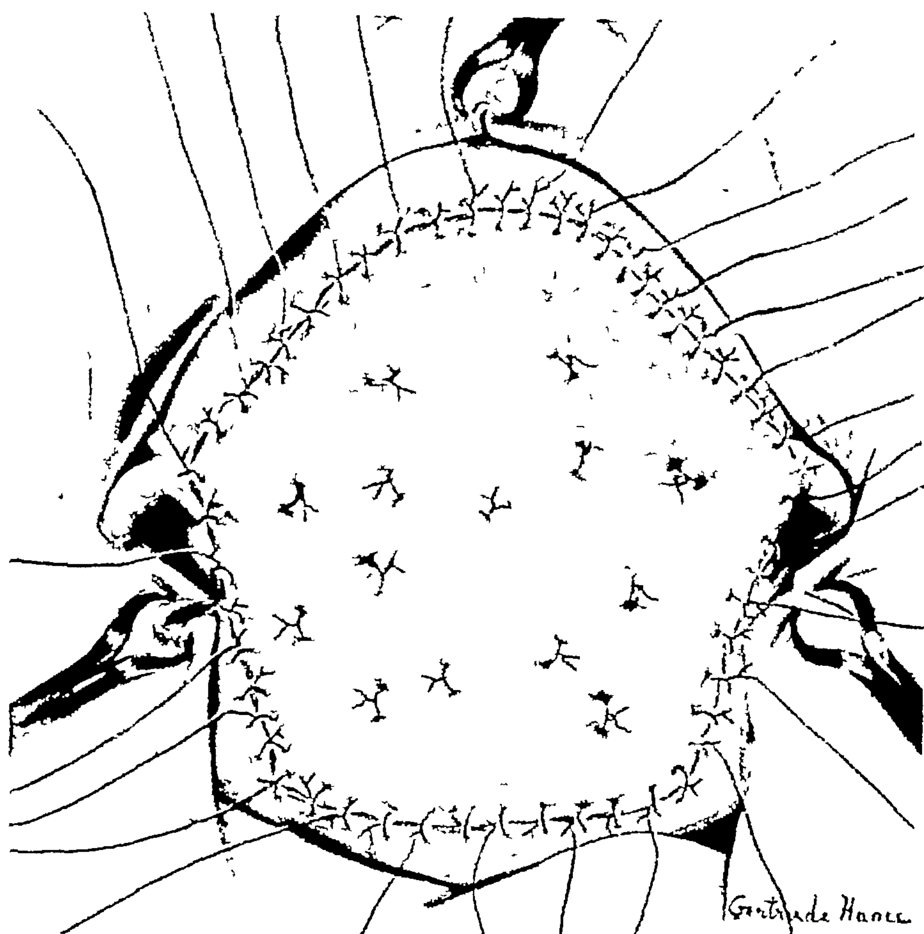


Fig. 71A Graft sutured in place on the neck The graft is sutured edge to edge in the defect with multiple fine interrupted silk sutures with the ends left long to tie over the dressing (stent type of fixation). Another suture is run between these, and the mattress sutures in the center of the graft also aid in fixation (the latter can be omitted in most locations)

this is a better technic than one in which the fat globules are cut off the raw surface of the graft after it has been detached from the donor area

APPLICATION AND FIXATION OF GRAFT

If the graft is of irregular shape, it must be taken with the pattern placed correctly and not turned around later To avoid this, suitable blue marks may be made on the graft to show the correct direction of its application

The graft is placed on the field and anchored carefully with waxed No 000 black silk sutures at key points, and then accurate sewing is done to try to obtain primary union between graft and defect edge all around Of course there may be some trimming to do but this should be done gradually or at the last place of fixation The correct tension to put on the graft can be described best as normal skin tension for a person of average weight, that is, not the tight tension found in an overnourished baby or woman and not the looseness found in the aged or debilitated person This is a matter of practice, but this description seems to be the clearest

Formerly, multiple stab holes were put in these grafts to allow for escape of blood and serum, but they leave ugly scars and usually can be omitted if sufficient care is taken to see that the field is dry and to get a dressing with uniform pressure throughout.

Interrupted deep mattress sutures can be put in through the graft where necessary to hold it down into any depressions or where there is uncontrollable movement, such as over the thyroid cartilage (Fig 71A).

DRESSINGS

The dressing is done in much the same manner as for split grafts, using 1 or 2 layers of fine-mesh grease gauze next to the graft Surgical waste is applied over this (Fig.

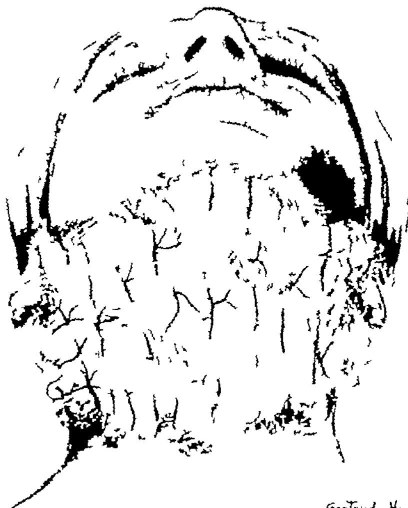


FIG 71B Suture fixation with the long edge sutures tied snugly over surgical waste. A layer of fine mesh grease gauze is placed be tween the graft and the waste and an over all large dressing is applied after ward to provide fur ther fixation and immobilization of the head.

71B) care being taken to tuck separate por tions of it down into any depression firm pressure is obtained with gauze rolls band age and adhesive Joint movement must be avoided if it will tend to dislodge the graft or cause bleeding and some splinting can be used Crinoline usually will suffice but plas ter or wood splints may be used About the neck copious head dressings and fixation of all neck movements must be done

On the face it is often necessary to close the eyelids on the involved side and to wrap the dressing over them In this instance the conjunctival sac is washed out and a small amount of white petrolatum or other safe ointment is instilled The lids are taped or sutured shut being careful to have all lashes turned out. The lids are covered with a sheet of fine mesh grease gauze and then a pad of fluffed-out waste over which the pressure dressing is applied

In grafts close to the mouth the anus or the urethra it may be desirable to build up a dam of waterproof ointment near the edge of the graft to avoid future contamination A silicone ointment is very useful for this or 5 per cent zinc oxide in petrolatum may be used if preferred

CLOSURE OF THE DONOR AREA

The donor area will granulate and heal by secondary intention unless some provision is made for its closure In small or roughly elliptical grafts often the edges can be undermined and brought together Inter rupted silk vertical mattress sutures being very useful for this purpose Sometimes round or square defects can be closed by

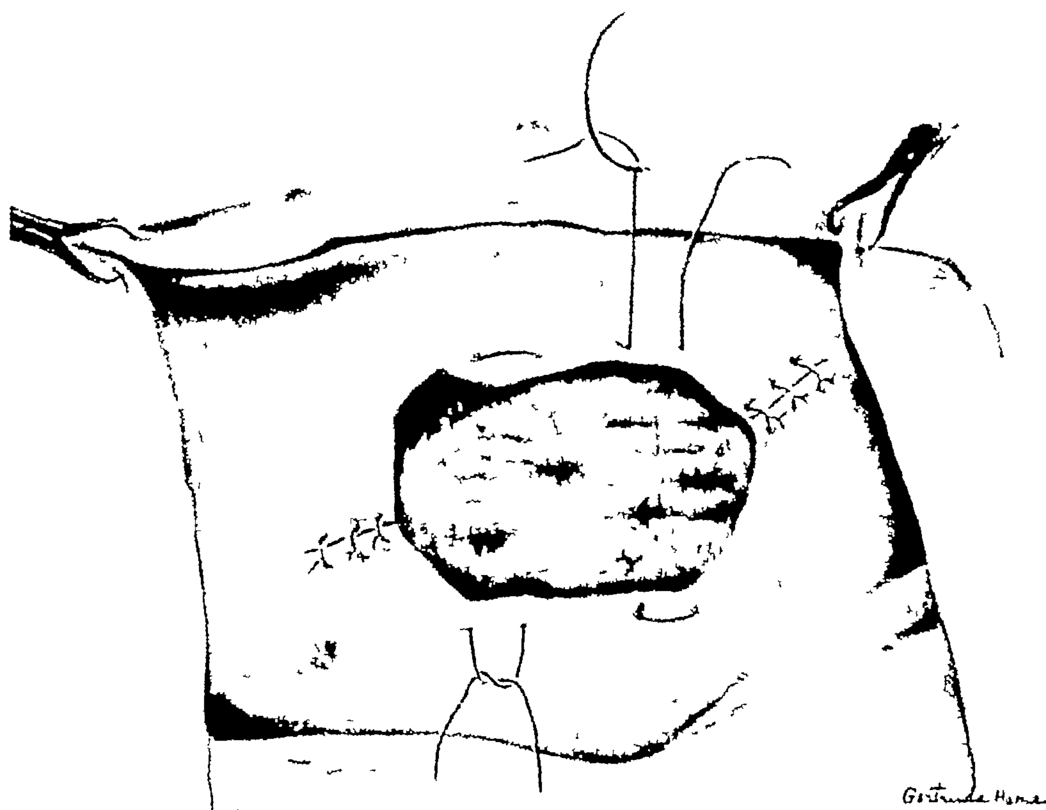


FIG 72 Reducing the size of the abdominal donor area preliminary to covering it with a split graft Often smaller donor areas can be closed without grafting by undermining and suturing, or by swinging local flaps In any event, an attempt is made to get primary healing of the donor area

undermining and switching local flaps to effect a closure in the shape of a Y, a T or an H Larger defects usually should be closed with a thick split graft, though sometimes the defect can first be made smaller by closing the ends and putting heavy wide, lateral mattress sutures all the way across underneath the center of the wound (Fig 72)

SUBSEQUENT DRESSINGS

The first dressing is often done on the 5th day but may wait an extra day or two if one is satisfied with the cleanliness of the area and the security of the fixation Grafts close to the eyes, the nose or the mouth probably should not be allowed to go longer than 5 days before the dressing is changed

The dressings are done in the same manner as for split grafts except that the edge sutures are left in a little longer—usually from 8 to 10 days Full-thickness grafts are a little slower in healing in at the edges and usually will not begin to grow new epithelium to heal any areas of loss in them until nearly 3 weeks after they are applied Subsequent dressings may be done at intervals of from 1 to 4 days, depending upon the general appearance and cleanliness of the graft

Serpiginous ulcers may appear occasionally in these grafts They usually start as a tiny area of full thickness or sometimes only epithelial loss which is seen at the first dressing They have a strong tendency to spread without the appearance of much inflammation or discharge and, of course, leave scars in the grafts when they are finally healed These ulcers are poorly understood but are possibly associated with the symbiotic growth of low-grade organ-

isms The best present method of dealing with them seems to be to trim out any slough or to peel off any blistered epithelium dry the area thoroughly and apply 10 per cent Mercurochrome or other antiseptic of choice If there is any tendency toward burrowing under the periphery, the overhanging edges can either be excised or else care must be taken to get the drugs in underneath them Usually they are dressed daily until the process of dissolution has stopped and healing is well under way

The final edge scars on tiny full thickness grafts may be almost invisible but on larger grafts they may be even worse than with split grafts Gradual excision of these in stages will often do a great deal to improve the final appearance

TIE-OVER DRESSINGS OR SUTURE FIXATION [1]

This method of fixation has sometimes been called stent" fixation and Ollier Thiersch grafts thick split grafts or full thickness grafts can be used Originally the name was applied only to grafts which were put in over a wax mold with the edge sutures left long and tied together over the form but it is currently used for this type of fixation regardless of the material employed in the form Surgical waste is now used for nearly all these grafts except those inside the mouth where dental wax or stent is still employed

This type of fixation is very desirable for grafts put on the neck the cheek eyelids lips ears or inside the mouth the nose or the orbit and at times it is advantageous on the abdominal wall fingers and other locations In general it is used when satisfactory pressure and fixation cannot be obtained by the usual external dressing alone

When used multiple interrupted sutures are put through the junction of the graft and the surrounding skin all the way around and the ends are left long and tied



Fig 73 "Tie-over fixation of a full thickness graft on the lateral aspect of the neck Dressing consists of fine mesh grease gauze waste and gauze flats with the long edge sutures tied over all of it A larger outer dressing is applied after this incorporating the head and the upper chest.

over a pad of waste (Figs 70 71 and 73) or other type of form In some areas such as the eyelids it may be advantageous to use only a small pad of waste and pull the graft out partially around the dressing when tying the long sutures but in other places such as the cheeks a relatively large pad of waste overlapping the edges can be used so that the sutures pull the graft up snugly against the form The usual type of external pressure dressing is used in addition to the "stent fixation in most instances

11

Pedicle Flaps

GENERAL CONSIDERATIONS

Pedicle flaps consist of the full thickness of the skin with the underlying subcutaneous fat and are left attached to both the donor and the recipient areas until a sufficient blood supply has developed from the latter They are used principally for restoring contour or bulk, in contrast with free skin grafts which are used for resurfacing Flaps are often a necessity in restoring lost features (Figs 74 and 75) or bridging over holes into cavities and may be required for padding over bony prominences Flaps are sometimes essential to bring new blood supply into an ischemic area, which could not support a free graft (cf Chap 12, "Permanent Pedicle Blood-Carrying Flaps")

Flap repairs in general are time-consuming and expensive for the patient and tedious for the surgeon, so that careful thought should be given to their necessity in each instance, especially as to whether as good or better results could be obtained with a free skin graft In case of doubt, a free skin graft could be tried first, substituting a flap later if it proves to be unsatisfactory Flaps are essential in certain types of repairs and produce better results than free grafts in



Fig 74 Arm flap repair in a young pe... loss and surrounding scarring involve most of nose a bett... ...ering the entire nose, rather only the major portion ... ...orge Hospital (Brown and McDowell Plastic Surgery ...

some others but it is surprising how the indications for them decrease as soon as the surgeon gets in the habit of thinking of free grafts first and becomes adept in handling them.

Flaps may be classified into *direct* flaps which are applied at the same time that they are raised and *delayed* flaps which are raised in stages to improve their blood supply before application They may be classified further as *local* flaps which are swung into the defect from immediately adjacent areas, and *distant* flaps

PLANNING FLAP REPAIRS AND SELECTION OF DONOR SITES

Once the necessity for a flap is determined the donor site should be selected with due consideration of all important details For facial repairs local forehead or neck

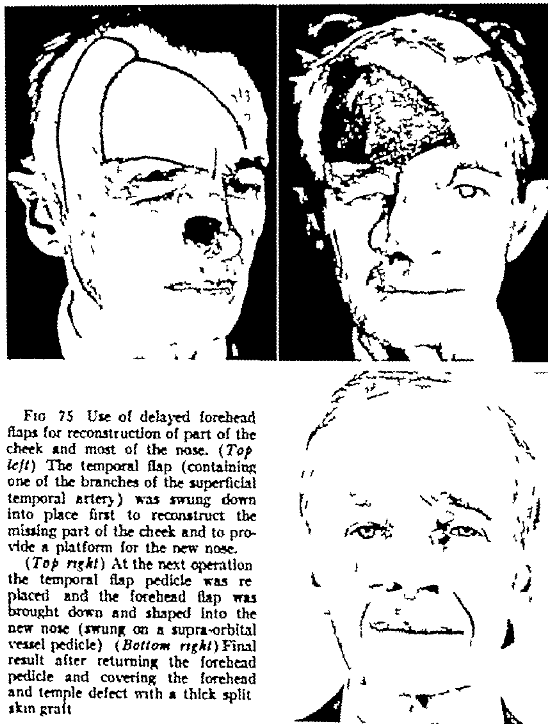


FIG 75 Use of delayed forehead flaps for reconstruction of part of the cheek and most of the nose. (*Top left*) The temporal flap (containing one of the branches of the superficial temporal artery) was swung down into place first to reconstruct the missing part of the cheek and to provide a platform for the new nose.

(*Top right*) At the next operation the temporal flap pedicle was replaced and the forehead flap was brought down and shaped into the new nose (swung on a supra-orbital vessel pedicle) (*Bottom right*) Final result after returning the forehead pedicle and covering the forehead and temple defect with a thick split skin graft

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FIG 74 Arm flap repair in a young person When loss and surrounding scarring involve most of nose, a better repair can be made by covering the entire nose, rather only the major portion Patient cared for at Valley Forge Hospital (Brown and McDowell· Plastic Surgery of the Nose, St Louis, Mosby)

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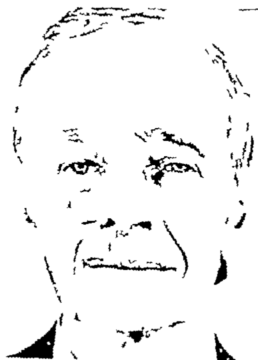


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flaps are apt to give the best color and texture match In nose repairs, especially, the rigidity of forehead skin presents a marked advantage (Fig 75) over the pale, soft skin of the chest or the arms, as the latter may be sucked in and collapsed with each inhalation In fingertip repairs, the firm tissue from cross-finger flaps or from the hypothenar eminences may be quite superior to a tiny, blobby flap from the abdomen, which may tend to contract into a small ball on the end of the finger Small repairs over the ball or the heel of the foot can sometimes be effected with a better weight-bearing surface by rotating a local flap from the arch

After noting all possible donor areas, from the standpoint of suitable skin and subcutaneous tissue, one should consider which area can be shifted into the defect the quickest, with the fewest operations, with the least inconvenience to the patient, and leave the least visible donor deformity These points may come into conflict, in which case it is necessary to decide how much each one counts with the patient at hand For instance, one might elect to repair a nasal loss in an old man with a forehead flap, as he might be more concerned with the quickness and the adequacy of the repair than with the resultant forehead scars The same loss in a young woman might be repaired with a direct arm flap, as one would not fear shoulder joint arthritis as much in her and she probably would object to any additional facial scars

When other factors are fairly equal, the time factor should be given much weight Direct flaps and local flaps may be considered first, using distant flaps only when they are not feasible In this connection, it is well to remember the mobility of the extremities and the head, that often the defect can be brought to the donor area rather than vice versa, or that each of them may be moved part way. The greatest amount of time is saved when the donor and the recipient areas can be brought together without intermediate transfers, thus avoiding caterpillar or jump flaps If the final decision is difficult, the alternate plans may be presented to the patient for his selection

After selecting the donor area, a pattern of thin felt, chamois skin or other suitable material is made of the defect, remembering to allow additional skin for lining, etc if necessary The pattern is enlarged as much as necessary according to the donor site selected If the forehead is to be used, only a slight excess is necessary, as these flaps shrink very little However, neck or chest flaps may shrink as much as one third, and arm flaps one half or more In computing the extra allowance, it is much better to end with a little extra tissue on the defect than not quite enough Then the enlarged pattern is laid on the donor area in such a manner that all of it except the pedicle can be lifted up and applied over the recipient area When this position on the donor area is determined, it is so marked by tracing around the pattern with a 5 per cent alcoholic methylene blue scratching in the lines with a mechanical drawing pen if necessary

At this time, the whole procedure is reconsidered with the patient, being certain that he understands the number of operations, the time required and the position of immobilization and is psychologically and physically prepared to go through with it

This planning is gone into in some detail because a little extra time spent at this point may save much time and effort in the actual execution of the plan Nothing is more annoying, or more unnecessary, than ending with a flap that is too small, a pedicle that is too short, or a joint position that is not endurable for the required time

SUITABLE RECIPIENT AREAS FOR FLAPS

A granulating area should be as clean for the reception of a flap as for a free skin graft. In fact, if there is any question of cleanliness, cover the area temporarily with

a split graft to get quick healing and subsidence of inflammation and then replace it with the flap later

A flap can pick up blood supply from the same areas that a free skin graft can, i.e., granulations fat fascia muscle periosteum etc. In addition, it can bridge over avascular areas such as bare bone, cartilage or tendon or over a cavity If the flap is to bridge such an area it is important to have a sufficiently wide blood supply around the periphery even excising some normal skin around the edge if necessary to get it A local flap will bring in its own minute supply (which is a marked advantage in some avascular areas) but all other flaps must be provided with a vascularized bed in the recipient area to nourish them and they are parasites on the recipient area

Flaps never should be placed over dead bone tendon or fascia, as the inflammation attending their subsequent separation may gravely jeopardize an overlying flap which is struggling for its own survival In general bare cortical bone or bare tendon which has been exposed for several days should be assumed to be dead unless proved to be otherwise by appearance of granulations on the surface

PROPER TIME SEQUENCE FOR FLAP COVERAGE AND DEEP WORK ON BONES TENDONS NERVES ETC

It can be taken as a surgical axiom that deep healing never can be better than the surface coverage In general the rule is to get final complete surface coverage and healing first and then after a suitable interval to go ahead with repair of the deeper structures

For instance a patient may come in several hours after an extensive hole has been blown out of the forearm with a large gap in the skin subcutaneous tissue muscles radius etc Usually it is best to do a debridement clean the wound splint the extremity in the best possible position and cover the wound immediately (but temporarily) with a split-skin graft to get a healed wound and prevent further contracture or infection The split-skin graft can be peeled off in 3 or 4 weeks and a direct abdominal flap substituted for it to provide adequate final coverage After the flap has healed and softened and all edema and reaction has disappeared (usually 6 weeks to 2 months) an incision can be made through the flap for deep work such as bone grafting nerve sutures tendon grafting etc. At this time the surgeon has a completely clean field and adequate surface coverage both of which are essential for the success of this deep work.

Occasionally if the wound is seen very early or is unusually clean the direct flap may be applied immediately without the intermediate split skin graft stage

Numerous instances have been seen where surgeons have tried to put in bone tendon or nerve grafts or have tried to plate fractures or suture nerves or tendons without adequate surface coverage and these are all doomed to failure from the start

Occasional instances have been reported where a satisfactory result has been obtained by simultaneous immediate deep work (such as bone grafting) and coverage with a flap The total number of these is probably rather small compared with the numerous failures that have been seen from this procedure

DIRECT FLAPS

A *direct flap* is one that can be applied to the recipient area at the same time that it is first raised Certain well known flaps containing named arteries and veins can be applied in this manner One example is a forehead flap with a lateral pedicle containing the anterior branch of the superficial temporal artery and vein Another is a full thickness lip flap swung on a vermilion pedicle containing the coronary artery and vein

In addition to these known flaps a direct

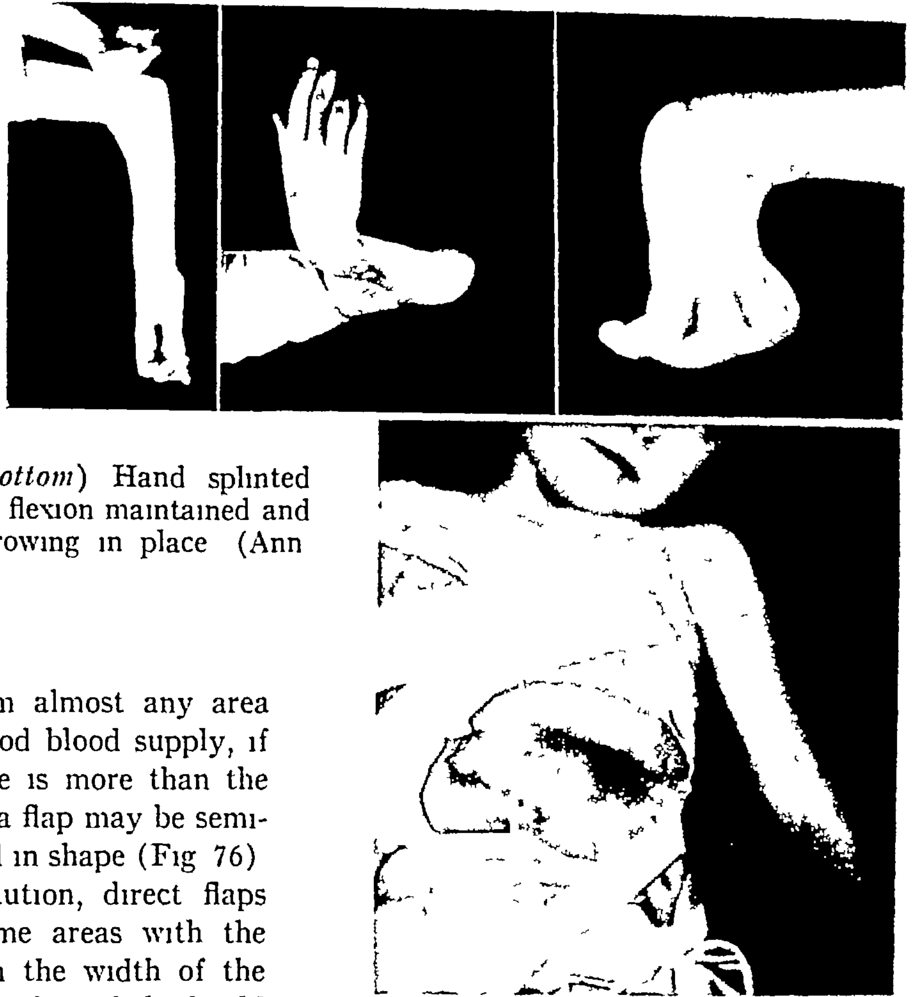


Fig 76 Direct abdominal flap to the hand (*Top, left*) Extension deformity of fingers and wrist following wide skin loss (*Top, center and right*) Voluntary flexion of wrist, but not much flexion of metacarpophalangeal joints obtained However, the hand in general is almost normal in function (*Bottom*) Hand splinted across the abdomen, with flexion maintained and direct abdominal flap growing in place (Ann Surg 107 969)

flap can be raised from almost any area having an ordinarily good blood supply, if the width of the pedicle is more than the length of the flap Such a flap may be semicircular or semielliptical in shape (Fig 76)

With considerable caution, direct flaps can be raised from some areas with the flap length greater than the width of the pedicle In such instances, the pedicle should be kept as thick as possible and be in the direction of the greatest known blood supply The flap is raised slowly, stopping frequently to apply tests for viability, and if there is question of this, it is usually better to stop and replace the flap, using a staged delay procedure instead

Sometimes a direct flap from the inner surface of the arm can be used for the restoration of part of the nose or other areas about the face Direct flaps are also raised from the abdominal wall for covering the forearm or the hand in some instances, especially when the covering of tendons is a problem (Figs 300, 301 and 76) An abdominal pocket is another type of direct flap which can be used in some of these cases, particularly for covering the dorsum

DELAYED FLAPS

A *delayed flap* is one which is raised in stages before transference to the recipient area (Fig 77) It can be narrower and longer, but in general the length should not exceed three times the width In the usual rectangular flap, cuts are made along the two long sides, and undermining is carried out from one side to the other If it is desired to line the under surface of one end of the flap with a skin graft, it can be inserted at this time, a full-thickness graft being better for this purpose than a split graft The flap is then sutured back down in place, and a pressure dressing is applied After 2 or 3 weeks the end can be cut across and resutured, and a week or two later the flap is ready for use if all swelling and edema has subsided The purpose of raising such a flap in stages is to permit gradual hypertrophy of the blood vessels in the pedicle and possibly to accustom the tissues in the flap to a lower oxygen tension or a poorer circulation.

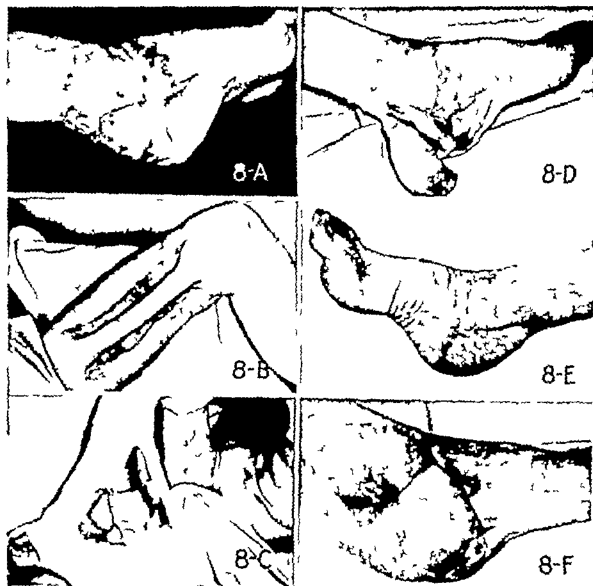


FIG 77 (A) Deep solid scar around the heel Chronic ulcer healed after being "dressed" with a thick split graft as the best preparation for the wound and the area to receive the flap (B) Tubed flap prepared in a single stage and defect grafted rather than pulled together or left open (C) Fixation of cross-leg position. (D) Flap off (E and F) Completed flap with wide restoration of region (Brown J B and Cannon Bradford The repair of surface defects of the foot Ann Surg 120 417-430)

LOCAL FLAPS

A local flap is one rotated into the defect from an immediately adjacent donor area. It may be raised and transferred directly or after one or two delays according to the size the shape and other circumstances It is often possible to leave the pedicle intact permanently so as to bring a new blood supply into the recipient area (cf Chap 12) Local flaps usually can be transferred with greater certainty and in fewer operations than distant ones so that the possibility of using one should be carefully considered in each patient requiring a flap repair (Fig 88)

DISTANT FLAPS

A distant flap is one prepared at some distance from the defect the two areas are brought together by movement of the extremities or the head or by a caterpillar or jump technic. Distant flaps are usually more

hazardous and are apt to require more stages than local ones, so that the possible use of a local flap should be carefully considered first in each instance. The most useful distant flaps are probably cross-leg flaps for the lower extremity, and arm flaps for certain defects about the head and the neck (Figs. 74, 77).

FLAT FLAPS

A flat flap is one in which the entire flap, including the pedicle, is transferred in its natural flat position, without additional preliminary operations to tube the flap, and without additional subsequent operations to untube it. A flat flap and pedicle is apt to maintain a better blood supply and to be subject to less torsion and central venous thrombosis than a tubed one. A flat flap also requires less operative manipulation and handling than a tubed one. If it is desired to have the donor site and the undersurface of the pedicle closed for cleanliness, this can be done with a split graft, with much less manipulation and endangering of the flap than tubing would entail. There are very few instances in present-day plastic surgery where the tubing and untubing of a flap is not disadvantageous. The use and the advantages of a flat flap should be carefully considered before embarking on such an indirect and prolonged procedure (Fig. 266).

TUBED FLAPS

A tubed flap is a delayed, rectangular one in which the two long edges are raised, with undermining between, and sutured together underneath to form something that looks like a suitcase handle. The skin edges on either side of the flap may be brought together under the tube and sutured to close the defect, or the defect may be covered with a split graft. This tubing has been described by Filatov and Gillies and may be advantageous when using a long flap, as the pedicle is entirely healed (Fig. 77). It is a natural development, as the raw surface of any pedicle tends to heal, contract and curl into a tube while the flap is up in place and the usual difficulty comes later in attempting to flatten out the pedicle when replacing it in the donor area.

CATERPILLAR FLAPS

A caterpillar flap is a tubed one which is raised at some point remote from its destination and then is brought up to the latter site by turning it end over end in stages. It is probably the most laborious of all types of repair and most subject to losses because of the multiple transferences.

JUMP FLAPS[1]

A jump flap is usually a tubed abdominal flap which is temporarily attached to the wrist, with the upper extremity being used as a vehicle to bring it up to its destination on the face or the neck. Both jump and caterpillar flaps are somewhat susceptible to central vein thrombosis, as a result of the sluggish circulation, and this may produce some loss at the end. However, an open jump flap (Fig. 311) from the abdomen to the forearm to the leg is often useful where a cross-leg flap cannot be used.

ISLAND FLAPS

An island flap is a direct one with the pedicle consisting only of the supplying arteries and veins. One usually can be obtained from the forehead for obliteration of an orbit (Fig. 78) (when the globe and the lids have been destroyed) by palpating one of the anterior branches of the superficial temporal artery, cutting over it and isolating it with its accompanying veins and an attached flap of skin and fat at the end. Then a tunnel can be made for the pedicle, and

[1] *A method of delaying a jump flap by turning it in on itself first in a pocket and later attaching it to the carrying wrist has been described by Cuthbert under the title of "marsupial flap." This leaves a pocket in the abdominal wall which can be surfaced with split grafts. In transferring it to the arm, the turned-back skin edge on the wrist is attached to the upper free edge of the folded abdominal flap.*





Fig 78 Island forehead flap used for obliteration of orbit Usually this is done when the globe and both eyelids are entirely destroyed Flap with attached artery and vein (which has been carefully dissected out) is put through a tunnel to the orbit

the flap is introduced through it into the orbit Similar island flaps from the scalp with one of the posterior branches of the same artery can be used for the replacement of eyebrows (Fig 79)

CROSS-LEG FLAPS

A cross-leg flap can be invaluable at times but involves about the most manual labor of any procedure in surgery and is subject to more complications and limitations than is popularly supposed Many surgeons who



Fig 79 Island flap reconstruction of each eyebrow from the scalp Final appearance shown in Figure 326

had successful experiences with these flaps on young, healthy athletic soldiers in World War II have been surprised at the difficulties encountered in later civilian experience with aged or obese patients, who may have varying degrees of arthritis or vascular disease

The lower leg and the foot are out on the end of a peninsula and present difficult problems for bringing in new tissue for repair In any such defect, the surgeon should carefully consider whether a satisfactory repair can be accomplished with a free graft, in this connection, free grafts function quite satisfactorily on the sole of the foot, provided that sufficient subcutaneous padding is present The next consideration should be a local flap, fairly large defects on the leg can be covered satisfactorily by rotation of delayed local flaps, on the sole, local flaps can often be rotated from a non-weight bearing area to a weight-bearing surface If a local flap cannot be used, the next consideration is a cross-leg flap, then an open-jump flap Caterpillar flaps and amputation are the last considerations

If the defect is large enough to require a cross-leg flap, usually it will be necessary to take it from the opposite thigh (Figs 85 168 and 170) The lower leg will seldom supply a flap of sufficient size, and it presents additional hazards associated with denuding of padding over the fibula or the tibia There is probably no reason for ever cutting into the opposite foot; every effort should be made to preserve at least one undamaged foot for the patient to stand and walk on

It is essential that the patient understand the entire procedure, and that he be prepared to go through with it It is well to experiment with various positions before the operation to determine the one most tolerable for him The flap will usually have to come from the anterior, the anteromedial or the anterolateral surface of the thigh The easiest position is usually with the donor extremity nearly straight and with the bent knee of the recipient extremity about halfway between a forward and a lateral position; extreme abduction or lateral rotation of the hip on the recipient side is an almost unbearable position for many patients after a few hours The required positions are usually not too bad for young patients but may be unbearable for patients over 40 or 45 years of age, though this is determined more by the condition of the joints than by any chronologic age Obesity makes the whole situation much more difficult

If the flap can be designed with a short, broad pedicle, it may be possible to do a direct transference, more often, it will be necessary to raise the flaps by one or two delays The donor area and the undersurface of the pedicle may be covered with a split graft at the time of transference

A pressure dressing is applied over the transfer area, without pressure or torsion on the pedicle Immobilization is usually accomplished with a double hip plaster spica to the toes, with an incorporated wood crossbar between the thighs, and a wood stand under the recipient knee Prepared splints of metal or plastic can also be used, if preferred About 17 or 18 days is usually required for transference Extreme care is used to pad well over all bony prominences and to avoid undue weight-bearing of the recipient extremity over the anterior surface of the donor thigh The location of the peroneal nerves is important to bear in mind

CROSS-LIP FLAPS

A cross-lip flap is a shield-shaped, or triangular, flap of the full thickness of the lip, rotated into a defect of the opposite lip, on a tiny pedicle of vermilion and the adjacent coronary artery and vein This can be done as a direct transfer but requires careful planning About one third of one lip can be rotated as a flap into a defect as large as one half of the opposite lip and the resultant balance will usually be satisfactory particularly in older patients (Figs 80, 81 and 82).

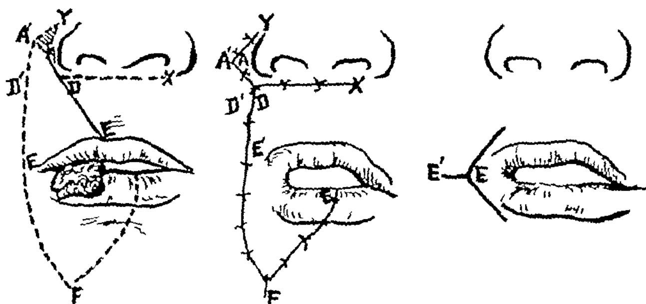


FIG 80 Cross-lip flap technic turned from upper lip to lower lip around the corner *of the mouth based on a tiny pedicle* containing the coronary artery It is seldom necessary to excise the triangle A A Y and to make the cross-cut D X. (*Right*) Shows *a later operation to pull the* new corner of the mouth over into better position



FIG 81 Cross-lip flap technic to fill in large defect in the center of the lower lip A flap is switched from the side of the lower lip into the central *defect first and then* the resulting side defect is filled with a flap rotated down from the upper lip in the usual manner

In transferring any cross-lip flap the mucocutaneous junctions are marked by puncturing in points of methylene blue on both sides of the defect and on both sides of the flap incisions *before the operation is* started this prevents confusion as to the exact location of these borders later in the operation

For lateral defects a flap is raised from the opposing segment of the opposite lip based on a medial pedicle and rotated into the defect so that the pedicle forms the new corner of the mouth This new angle of the mouth is advanced laterally at a later operation by a Y Y maneuver to restore symmetry between the two angles of the mouth

Central defects can be filled in two different manners A lateral flap from the same

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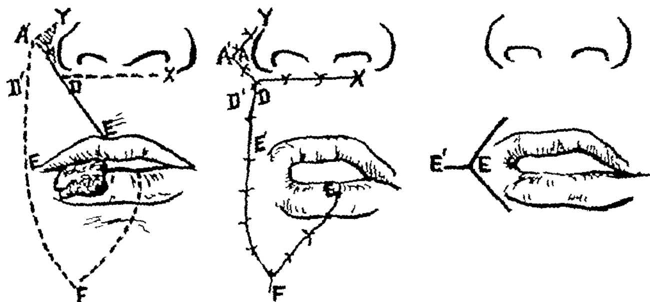


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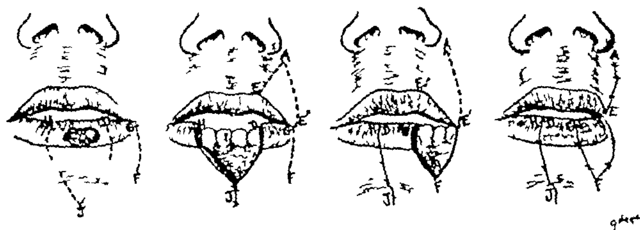


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Central defects can be filled in two different manners A lateral flap from the same

lip can be shifted over and the defect thus created can be filled by a cross-lip flap, as noted above The other method is to use a cross-lip flap across the center of the mouth from the opposing central segment of the other lip, this requires a temporary pedicle across the center of the mouth which is cut after 10 or 12 days This latter method necessitates the mouth s being closed for 10 or 12 days (with feeding by tube or syringe) and is done most safely under local anesthesia

For any cross-lip flap the mucocutaneous points are punctured in, and the borders of the defect and the flap are marked in, with 5 per cent alcoholic methylene blue and a mechanical drawing pen The incisions are lightly made with a No 15 blade and then the openings are made through the lip at right angles to the surface, cleanly and accurately with a No 11 blade The exact location of the coronary vessels is noted when the lateral border of the flap is raised, and extreme care is exercised to avoid cutting these vessels when nearing the pedicle on the medial side The donor area is closed before suturing the flap in its new location Closure is done with interrupted fine sutures, mucosa first, then muscle, and skin last A strip of wide elastic adhesive, from one temple to under the chin to the opposite temple, will remind the patient to keep his mouth closed and plaster fixation is not necessary

CROSS-ARM FLAPS

The cross-arm flap can be used for getting a soft, flexible, flap into the web space between the thumb and the index finger To see how this works, one can grasp his opposite arm just above the elbow The flap is a direct, semicircular one from the opposite arm, with the pedicle based superiorly

CROSS-FINGER FLAPS

The cross-finger flap is an old established procedure of somewhat limited utility Most defects on a finger can be covered best with a free graft, if an ordinary split graft would be too thin, it may be possible to get a thicker and softer coverage by using a full-thickness graft from the clavicular area.

If a free graft will not be satisfactory, next consideration may be given to rotating in a local flap and grafting the donor area Nearly all finger defects can be covered by one of these two methods

Occasionally, a flap from an adjacent finger may be advantageous (Fig 83) If so, it should be raised in such a manner as to protect the nerve supply in the donor finger and to avoid exposure of tendons in the



Fig 82 Cross-lip flap (*Left*) Cancer paste defect with large recurrence below it Widely *resected and filled in* with *cross-lip flap* as shown in photograph at right This avoided the old German "face-slashing" operations, of advancing or rotating in large lateral flaps with resulting better appearance and better sphincter function here



FIG 83 Cross-finger flap technic. (*Top*) Punch-press defect with tuft of bone gouged out (*Center*) Cross-finger flap in place for 18 days (with split graft growing on donor finger during this time) (*Bottom*) Detached and final result

donor finger In older patients the immobilization may result in two stiff fingers instead of one

The use of an abdominal flap for a small finger defect is mentioned only to suggest that it usually results in wadding up into a little doughy ball that is more of an annoyance than a help

FINAL PLANNING FOR A FLAP REPAIR

As mentioned before extra-detailed and repeated planning of flap repairs may save time in the end and be the best assurance of success

The defect should be studied again making certain that a flap repair would be better than a free graft and that the defect is in condition to accept a flap Several days of wet dressings and cleansing may be necessary on a dirty defect or it may be best to get it cleaned up by first healing it with a split graft Any devitalized tissue must be removed If the area is excessively ischemic the possible use of a permanent pedicle blood-carrying flap should be considered

Possible donor areas are reviewed again so that the best one may be selected The possible shrinkage of the flap is estimated and the pattern of the defect is enlarged a corresponding amount and marked out on the donor area By pattern and thread measurements it is made certain that the flap will reach without tension and without undue torsion on the pedicle Then it is decided whether the flap shall be prepared as a direct one or delayed in stages Finally it is made certain that the patient is aware of each stage the time and the positions involved and is prepared to go through with it.

RAISING THE FLAP AND TESTS FOR VIABILITY

In raising a direct flap, the distal portion is raised first and then step-by-step back toward the pedicle, stopping each time to be certain that the blood supply is still all right As one approaches the pedicle, the flap is kept as thick and wide as possible If there is question as to the blood supply at any time, the flap is replaced, and the procedure is converted into a staged one.

In the final raising of a delayed flap, the edges are cut around with a knife, and often the second undermining can be done with the finger or by blunt dissection

After raising, the flap is wrapped in a few moist sponges and replaced in its bed for a few minutes, to recover from any vasospasm that may have occurred Then it is finally tested for viability

Viability tests are many, but the more complicated ones are uncertain and difficult to carry out at the operating table The simple test of wiping the distal end with moist gauze and thereby securing multiple oozing points is perhaps the most reliable The over-all pink color of a flap with no evidence of color change or demarcation in any part, is always encouraging The "flash test" is useful pressing down on the distal skin with the looped handle of a hemostat for a second and then observing how long the blanched area requires to regain its full color. If the flap passes all of these tests, particularly when rotated to its new position, it is almost certainly ready to use

CLOSING THE FLAP DONOR AREA

As noted before, flat flaps are preferred to tubed ones for most purposes. If it is desired to seal the pedicle a split graft can be put on the undersurface of the pedicle and carried on down over the donor area

Some donor areas can be closed by undermining and suturing up to the point where the pedicle will be replaced, if this does not constrict the pedicle in any way At times, it may be best to dress the donor area open and close it at the time the pedicle is returned

SEVERANCE AND RETURN OF THE PEDICLE

If the flap does not have a permanent pedicle, the question always arises as to when the pedicle should be severed and returned to its original locale Various complicated tests have been devised for determining this, but most of them are subject to various technical difficulties and errors

In general, few pedicles can be severed in less than 2 weeks (except 10 to 12 days for cross-lip flaps), and few will require longer than 3 weeks, 17 or 18 days may be an average figure, if the recipient site offers good blood supply and wide contact

After waiting the estimated period of time, the pedicle can be compressed with a rubber-shod clamp, using rubber bands on the clamp to apply the pressure, for 15 or 20 minutes The flap will often become quite pale for a few minutes and then regain its normal color with a rapid "flash" In such instances the pedicle can be severed at any time If there is question, or if the pedicle is very broad, it may be best to make a partial cut across it from each side under local anesthesia, leaving about the central half intact A day or two later, the remainder of the pedicle can be clamped and tested as above

In deciding *where* to cut the pedicle, one should consider whether a hanging tail will be useful in completing the repair For instance, in arm flaps to the nose, a long hanging tail is usually left attached to the new nose for 2 to 4 weeks, as there will be considerable shrinkage, and it is necessary to have enough finally to turn up and in to line the inside

After the pedicle is severed, any granulations or split graft on the under side may be excised, and any necessary excisions carried out in its old bed in preparation for its return If the pedicle has tended to tube, it may be necessary to make several longi-



Fig 84 (A) Extensive loss of sole of foot. (B) Split graft applied to obtain quick healing, but obviously an insufficient pad to allow the patient to walk.

tudinal cuts on the underside so that it can be flattened out completely Then it is carefully fitted back into place and fixed with subcutaneous and skin sutures as necessary, followed by a pressure dressing

The remaining raw edge of the flap can be trimmed and fitted into place now or later according to the circumstances This is not a good time to undermine any part of the flap whatsoever

LATE DEFATTING OF FLAPS

If flaps are not used except where bulk is required if they are prepared and applied in the proper thickness originally, and if abdominal flaps with their coarse lumps of fat are avoided whenever possible this "defatting" nuisance can be largely eliminated

When necessary it is usually best to wait a month or two open up one side of the flap excise the excess fat and a little bit more, replace and resuture the flap and apply a firm pressure dressing The procedure may have to be repeated later from the other side, especially if the patient gains weight This can develop into a repeated annoyance and it is well to avoid it by foresight, when possible.

PREPARATION OF THE RECIPIENT AREA

Prior to the transferring operation the recipient area is made as clean as possible by daily cleansing wet dressings antibiotics etc. or even by temporary split graft coverage if necessary (Fig 84)

At this time, any scar epithelium around the edges is excised, and granulations are sliced off down to a firm smooth bed with a multitude of fine oozing points An ade





FIG 85 Same patient as Figure 84 Restoration of sole with pedicle flap from opposite thigh (A) Plaster fixation (B) Good functioning sole which allows patient to get around and pursue all normal activities However such a flap does not metaplase into true plantar skin and often requires protection with a sponge-rubber pad in the shoe, or some other device (C) Grafted donor site on thigh Compare size with (B) Sufficient allowance for shrinkage and trimming should be made when any flap is designed



quate minute blood supply is necessary for the "take" of a parasitic flap (e g , one that will not have a permanent pedicle) If the edges of the defect are excessively thin, it may be necessary to sacrifice some normal skin to get back to good thick tissue It is often worth while to undercut the edges of the defect slightly and turn them up for best suture fixation of the flap Sharp corners or V's or darts are avoided whenever possible

APPLICATION OF THE FLAP

The flap is now moved into position and anchored with multiple interrupted sutures of fine catgut or No 000 white silk Good approximation of subcutaneous tissues and deeper tissues is essential all around the edges except where the pedicle comes in If this is done accurately throughout, few if any skin sutures will be necessary

DRESSINGS AND FIXATION

A dressing is applied with pressure over the part that is to be transferred but with no pressure, constriction or tension on the pedicle Any torsion of the pedicle should be minimized as much as possible and the adjacent joints and parts are immobilized

Fine mesh grease gauze is applied immediately over the flap then a layer of waste and compression by means of a gauze roll or Elastoplast The pedicle donor area is dressed similarly The pedicle itself is covered with grease gauze a few flats and a loose dressing

Although the adjacent joints and parts must be immobilized plaster fixation is seldom necessary except in the case of cross-leg flaps For instance in arm flaps to the face adhesive and Elastoplast fixation is sufficient and is much lighter and more comfortable for the patient In all fixations bony prominences and nerve points are padded and care is taken to prevent any pressure sores

POSTOPERATIVE CARE

The dressings and the fixation are arranged in such a manner that easy and frequent access to the flap may be obtained for inspections The first such inspection is then carried out in an hour or two and thereafter as indicated However it is important to replace elastic pressure on the flap each time as more flaps probably die from venous stasis than from arterial insufficiency

If the flap is dusky on inspection a further clue as to its status can be obtained by its flash time " Measures to combat this may include being sure that the pedicle is loose and free from hindrances elevation of the area and a continuously good pressure dressing on the flap itself Leaving the flap open massaging it applying suction applying icebags etc., are all measures which probably do more harm than good Extra care in the planning and the operation will avoid most of these difficulties

The flap and the pedicle are kept clean and redressed as often as necessary throughout the postoperative period

COMPOUND FLAPS

Various bizarre procedures are reported from time to time in which bone or cartilage, or some other object is first buried under a flap in its original donor location and later is transferred along with the flap Such a flap is known as a compound flap Skin lining may routinely be put under flaps and transferred with them in this manner Experience to date with the other compound flaps probably would not merit their use in a routine manner

Similarly there are occasional reports of putting a bone graft in an open wound and immediately covering it with a flap or doing the same thing with cartilage metallic implants etc. Enough failures have been seen from these procedures to suggest that they be discontinued

FAT FLAPS

Judging from the results seen it would seem that free fat grafts are rarely successful when any considerable amount of bulk is involved

A flap seems to be the most certain way of transferring fat even though it is cumbersome

In hemifacial atrophy a good filling of the face can usually be obtained with a fat flap and this has been done from time to time on our service for many decades (Fig 86)

A flap from the inside of the arm is used most often though a chest flap can be used with a little more difficulty

The flap is a long rectangle, with the pedicle at the elbow end and is delayed At the time it is raised for transfer a free skin graft is cut off the surface and applied to the donor bed underneath The flap is let into the face through a transverse in





FIG 86 Fat flap for restoration of contour Hemifacial atrophy, treated by single maneuver of inserting arm flap with split graft cut off the surface, up through incision under horizontal body of mandible (*Right*) Shows result 1 year later, with preservation of good movement





FIG. 87. (*Left*) Flap repair of burn contracture of neck (done elsewhere). This straight-line profile from the lip to the sternum is commonly seen in this type of repair. (*Right*) Restoration of the neck angle by cutting across the middle of the flap and inserting a free full-thickness graft Following this, the patient was able to swim for the first time after his accident. Also note reconstruction of helix of ear with small direct flap of mastoid skin

cision under the jaw Several long double armed sutures (straight needles) are passed through the upper end of the fat flap and then passed through adhesive tape patches in the temporal scalp and the outer end of the brow and then tied up in place The forearm is fastened over the head in the usual manner and from 17 to 18 days is sufficient for the transfer

ADVANTAGES OF SHORT BROAD PEDICLE FLAPS

Short, broad pedicled flaps have been used extensively in the past 15 years instead of tubed flaps They are most applicable to the hand and the arm following crushes and gunshot wounds that leave large defects (Figs 300 and 301)

These areas can be repaired with direct abdominal and chest flaps by using the principle of a short broad pedicle which will allow complete mobilization and immediate use of the flap There is rarely any need for delaying or tubing flaps for these repairs.

This procedure has been carried out in large numbers of patients and a valuable saving of patient hospital weeks has been possible Whereas long tubed flaps or delayed flat flaps have been known to require months of preparation this direct flap is prepared in 10 to 30 minutes and usually can be detached in 14 to 20 days Therefore the crippled extremity is freed of its scar by thorough dissection the flap is prepared accurately and at the same time the arm is "planted" under the flap with the result that in 2 or 3 weeks the arm or the hand can be detached from the abdomen and the wound closed This flap is soon ready for use or for any necessary deep work on bone nerve or tendon

Bone nerve and tendon repairs cannot be accomplished successfully through dense scar because the results of these operations can only be as good as the surface healing When deep repairs are attempted through excessive scarring the wounds may break down and wire foil screws plates and bone grafts may be lost The procedure outlined here is of marked importance in the preparation of many areas for necessary orthopedic or neurosurgical repairs

RESULTS OF FLAP REPAIRS

Flaps may give the best result or the only possible result in some instances but they are not without their faults In general the skin maintains its own color and texture quite well and facial repairs with forehead or other adjacent flaps match whereas flaps from more distant areas are apt to differ The chief difficulty however is that the thickness the heaviness the excess fat and the general blobbiness may markedly impair emotional expression or other movements and may actually create webs This is seen quite strikingly when large flaps have been put in from the lower lip to the suprasternal notch for repair of contracted necks (Fig 87) The flap may form an almost straight diagonal line from the lip to the sternum without any normal chin prominence or angle between the neck and the jaw Because of the constant weight the patient may tend to keep his mouth open or lips apart although closure is possible Another difficulty with flaps is that because of the laboriousness of the method shrinkage and unpredictable partial losses too little skin is often brought up to effect a satisfactory repair The amount of skin required to open widely some of these severe contractures may be more than anyone might predict

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Permanent Pedicle Blood-Carrying Flaps

USES AND ADVANTAGES

In repairing a defect in a heavily scarred area with diminished vascularity it may be advantageous to use a flap with a permanent blood supply coming in through a permanent pedicle that does not have to be detached from its donor site. Such instances are found in radiation lesions, in defects extending into bony cavities, as about the tibia and the foot where bone may have to be replaced as about the jaw, about the chest and the axilla, in densely scarred areas resulting from gunshot wounds, and traffic accidents, in extensive war injuries, in defects of the scalp with or without bone loss, defects following tumor removals where bone is exposed, as over the vertebral spines, the pelvis and the elbow, and in decubitus ulcers. This type of flap actually adds blood supply to the recipient site instead of



FIG. 88. Permanent pedicle blood carrying flap. (*Left*) Deep indurated radiation lesion of back of axilla for which a long series of operations had been proposed. (*Right*) Result of one operation, with flap rotated upward from lateral chest wall, bringing in new blood supply to the area.

being a parasite on the area as the usual distant flap does that has to have its pedicle severed

Along with the blood supply these flaps may carry some nerve supply that may give more tone to the final repair and possibly better sensation In designing and using these flaps however it is advisable not to sacrifice important adjacent nerve or blood supply or to distort other functions or features. These flaps are designed not so much for the method or the ease of preparation and manipulation as for the permanence of the pedicle and the blood supply Although they are rotated into position they are designated as to their function rather than as to their form and for this reason the term permanent pedicle blood carrying flaps is suggested These flaps have been mentioned previously but not by this suggested designation When a rotated flap island or arterial flap palate or Estlander lip flap or any type is used in which the pedicle does not have to be cut the same process is carried out but the design to obtain the permanent pedicle is the point of consideration here Along with this fundamental reason it may be that this is the simplest possible type of repair and may save many stages and much scarring as compared with the use of a distant flap

In resecting some of these defects the underlying nerves vessels tendons or joints may be so infiltrated with the fibrosed tissue that some of it may have to be left. In radiation lesions there may be scar tissue of reduced vascularity that may break down on slight trauma and may be responsible for subcutaneous calcification so that these areas are not normally resistant to trauma of any kind —surgical or mechanical For this added reason surgical procedures may be more difficult and this pathologic condition may make the use of permanent pedicle flaps more important

This deep fibrosis and vascular change may be the tissue effect that renders radiated tissue both early and late less resistant to other trauma. The microscopic appearance has been studied in tissue taken deep in such radiated areas and the study shows light-staining fibrous tissue only with vascular elements lacking to a marked degree and the tissue appears to be unable to cope with much trauma when considering healing possibilities

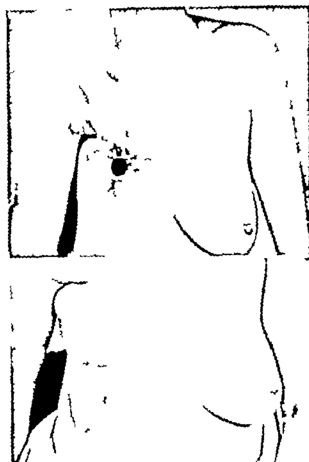


Fig 89 Permanent pedicle blood carrying flap (*Top*) Deep avascular sloughing radiated area 7 years after treatment for recurrence of breast carcinoma. Necrotic ribs pleura and pericardium and nothing to nourish a parasitic flap Patient almost demented from years of severe pain (*Bottom*) Result of excision and coverage with delayed permanent pedicle flap which brought its own new blood supply with it into the area

An example of the need and the use of this flap is demonstrated in a patient with a severe painful radiation lesion of the axilla following postoperative treatment for carcinoma of the breast (Fig 88) Prolonged effort was made by the patient to obtain relief with wide variations in advice being received Suggestions had been made as radical as transferring a thigh flap on the opposite right arm into position which would have required many operations and long hospitalizations and as radical as just letting the radiation lesion alo[illegible] using sedation.

In finally designing the repair for the axilla it was recognized that resection of the area was dangerous and that a soft pliable resurfacing would have to be supplied, with the best assurance of primary healing for protection of the nerve and blood supply to the arm A free graft was not indicated because of the extent and the depth of involvement

Accordingly a large permanent pedicle flap was designed from behind and lower over the chest and the flank and was carried into place in a single operation It was designed on the short broad pedicle principle rather than on the long narrow or tubed pedicle basis and the permanent result and rehabilitation was accomplished in a single operation with only 2 weeks of hospitalization. The donor area was repaired with split grafts at the same time This flap adds permanent blood supply as well as nerve supply to the area and gives the best protection to the underlying vessels and nerves and muscles After designing the permanent pedicle, the shift is that of a huge direct rotated flap The many other recommendations for complicated distant tubed or jump flaps have been circumvented by this single operation

If necessary for such a repair the flap can be delayed in several stages A delayed permanent pedicle flap with blood supply coming in from both sides is illustrated in Figure 59. This patient had a radiation slough including skin muscle and bone in the anterior chest

Her condition was desperate with recurrent hemorrhages from the internal mammary and intercostal vessels, necrotic ribs, and exposure of the pericardium and the pleura Pain was so great that she was thought to be a narcotic addict or to be involved with hopeless cancer and she had had advice from many sources that nothing could be done

It was evident that a free skin graft or



FIG. [illegible] Permanent pedicle blood carrying flap (*Left*) Deep hole under tibial plateau, with so much bone gone that the recommendation had been for a cross-leg flap, followed by bone grafting. (*Center and Right*) Coverage with a permanent pedicle, local flap Osteogenesis was rapid after this, possibly due to new blood supply so that bone grafting was not necessary.

a parasitic flap could not take and survive on this area. It was also obvious that débridement alone would accomplish nothing but exposure of more debilitated tissue which would then undergo further necrosis unless immediate permanent coverage could be applied

A permanent pedicle blood-carrying flap was needed here as a life-saving process with no question as to its own survival Accordingly a large thick delayed flap was designed below the defect and prepared in two preliminary raising stages At the final operation the flap was raised rotated into its new position and it was determined that its circulation was good A complete débridement of the defect was done removing devitalized chest wall and dead ribs and decorticating pleura and pericardium until a healthy base and margin was secured all around. The flap was then fixed in place and its original bed was skin-grafted

Primary healing occurred with good permanent coverage new permanent blood supply to the area and rehabilitation of the patient

It is felt that this procedure was a life saving one and that besides the fact that the area would not support a parasitic flap this patient could not have gone through the laborious stages of a distant tubed or jump or arm-carried flap

Where pedicles are very irregular usually they may be finally smoothed out depending on newly established channels from surrounding normal tissue but any folds or angles should be left for an adequate time to assure viability and restoration

When permanent pedicles are not available other types of flaps are utilized they are carried well into openings made out in the normal tissue to obtain blood supply

Deep holes in the tibia present one of the worst problems for obtaining an adequate per



FIG 91 Permanent pedicle flap used in war injury with extensive loss of mandible and soft tissues Flap rotated up from neck bringing good new blood supply into this scarred avascular area subsequent bone graft with complete take and firm union (Patient cared for at Valley Forge Hospital.) In other similar patients seen where a distant tubed flap was put up as a parasite on these avascular areas, there was often partial loss of the flap and sometimes repeated loss of subsequent bone grafts

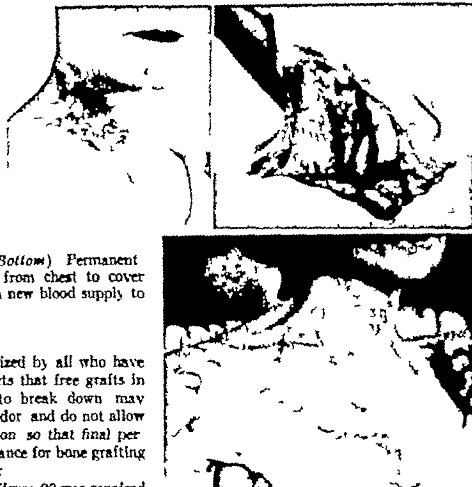


FIG 94 Permanent pedicle flap (*Top left*) Squamous carcinoma growing in extensive radiation burn as the result of radiation treatment (elsewhere) for benign goiter (*Top right*) Extent of resection necessary with exposure of great vessels and nerves Base still has a poor minute blood supply (*Bottom*) Permanent pedicle flap shifted up from chest to cover defect and bring its own new blood supply to area.

the pedicle It is recognized by all who have worked with these defects that free grafts in these cavities are apt to break down may wrinkle, have offensive odor and do not allow much new bone deposition so that final permanent healing and a chance for bone grafting may require a flap repair

The defect shown in Figure 90 was repaired with a permanent pedicle flap used after a preliminary delay in which the posterior opening and complete undermining was done. At the second and final stage the bony area was freshened the old free graft discarded the permanent pedicle flap put in place and the donor site repaired with split grafts. This allowed an adequate site for a bone graft under the tibial plateau (which the free graft repair would not) but the effect of the blood-carrying flap has been such that the bone graft has not been necessary although the exact added strength or amount of bone laid down cannot be determined In this as in many other bony defects the good effect of adequate thick soft tissue coverage is seen with confirmation of the dictum that the deep healing can be no better than the surface repair

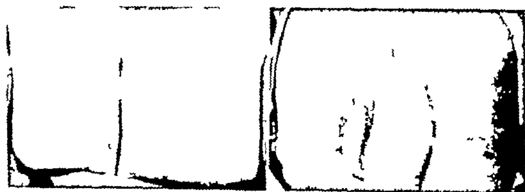


FIG 95 Permanent pedicle flap (*Left*) Radiation lesion of back, with hard white ischemic tissue clear down to the spine. (*Right*) Repair in one operation with new blood supply brought in by adjacent flap.



Fig 92 Permanent-pedicle flap, based on temporal artery (*Left*) Radionecrosis of forehead and skull, going through to dura Excised through to dura, and peripherally to bleeding bone and bleeding soft tissues all around Flap raised and swung down in same operation, and split graft placed on donor site (*Right*) Early result

manent repair, especially if the hole is just under the tibial plateau and there is question of adequate support for the knee joint In this instance the permanent pedicle blood-carrying flap gives the most efficacious repair, if available For use of the flap it is important that the bone necrosis be checked and there may be great benefit from the healing that closure with a free graft may give, so that the area is in the best possible condition for reception of



Fig 93 Permanent-pedicle flap, based on temporal artery (*Left*) Old chemical burn of forehead, with necrotic skull Medial scar is where someone had tried to shift a small double pedicled flap with further necrosis This was excised, including necrotic bone and a permanent pedicle flap was rotated in at the same operation (*Center*) Early result (*Right*) Late result.

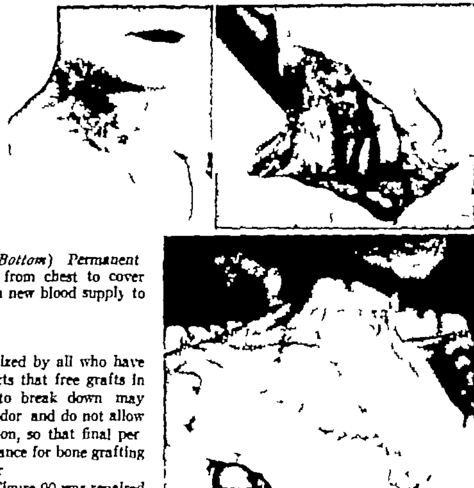


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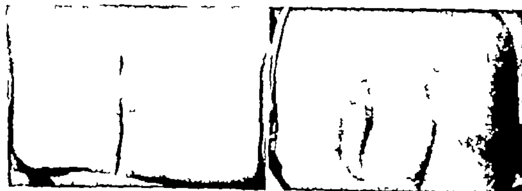


FIG 95 Permanent pedicle flap (*Left*) Radiation lesion of back, with hard, white ischemic tissue clear down to the spine. (*Right*) Repair in one operation with new blood supply brought in by adjacent flap



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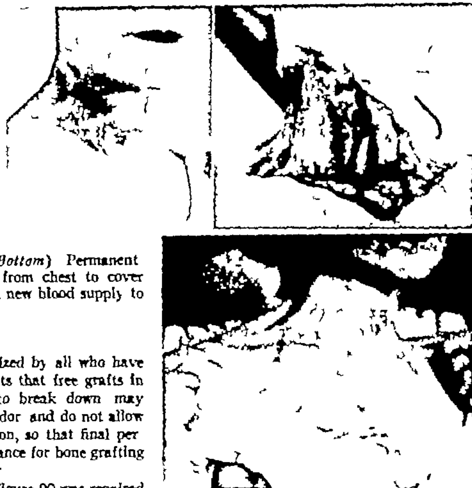


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FIG 95 Permanent pedicle flap (*Left*) Radiation lesion of back, with hard white ischemic tissue clear down to the spine. (*Right*) Repair in one operation with new blood supply brought in by adjacent flap

Severe jaw injuries, such as gunshot wounds, that require bone grafting are often best repaired with a permanent pedicle flap The flap is usually available lower down on the neck (Fig 91) and is moved up on two pedicles left permanently attached This provides a good minute blood supply in the bed for the bone graft and also excellent coverage for it, being definitely superior to parasitic flaps let in from a distance The neck defect can be grafted at the same time or later, with good function and smoothness often resulting

Skull, scalp, and forehead defects are often best covered with a permanent pedicle blood-carrying flap (Figs 92, 93, 227 and 267) If it is thought that a necrotic area in the skull may involve both tables, it is best to have the flap ready to put down for coverage before the dead bone is removed In many instances the flap can be designed as a direct one, with the temporal artery in the pedicle (Figs 92 and 93) so that the débridement and the coverage can be done in one operation, in other instances, it may be necessary to design a delayed flap which is prepared in stages

For neck defects a flap is usually available from the upper chest and is indicated in deep losses, as from radiation effect and radical tumor removals Replacement clear to the trachea has been made following radical resections for malignant radiation lesions, as lifesaving procedures (Fig 94)

Back lesions, particularly in the midline, may have very poor blood supply and may require a permanent pedicle flap for certainty of repair (Fig 95)

Decubitus ulcers are frequently repaired with rotated permanent pedicle flaps, and this occasion is taken to mention the futility of pulling or advancing flaps into place by pulling lateral flaps together after extensive undermining. This often results in loss of flaps and more scar, so that a final flap is difficult to obtain If permanent pedicle flaps can be designed and moved into place without tension the best repairs can be expected (Fig 138)

The foot on both plantar and dorsal surfaces is frequently repaired with permanent pedicle flaps in instances of deep dense scarring over relatively small areas, but of such nature as to be painfully crippling, as seen in gunshot wounds, warts, radiation lesions and traffic injuries (Figs 166 and 167) Careful evaluation of the donor site is important here to avoid uncovering bearing areas that might give more crippling.

PARASITISM OF ORDINARY FLAPS

The ordinary flap is nourished through its pedicle during the early days, then from both the pedicle and the recipient area, and after the pedicle is severed and returned the flap remains as a parasite on the recipient area

If the flap has to bridge an open space, such as the mouth or the maxillary antrum no blood supply is available from underneath, and nutrition is derived entirely from the borders to supply the central segment In such instances, the border attachments must be sufficiently wide on every side, and it may even be necessary to cut away a strip of normal skin all around the defect in order to get a sufficiently wide border attachment in every place The same situation obtains in bridging large areas of bare bone, bare tendon, cartilage, radiated areas, or areas ischemic from other causes In all of these instances, the use of a permanent pedicle blood-carrying flap should be considered

NOMENCLATURE OF PEDICLE FLAPS

In considering flaps designated according to their own physical characteristics, many variations have been noted and reported Of the group similar to permanent pedicle flaps, there may be mentioned such descriptions as rotated, adjacent, French, Estlander, island and arterial, as these may not

need to have their pedicles severed, although they are not designed for this reason or advantage.

Of the parasitic group that are brought from a distance are included tubed, flat, pancaked direct delayed pocket, marsupial, glove, thoraco-epigastric, cross-leg, cross-arm cross finger, cross-lid, some cross-lip, triangular, wrist-carried jump, caterpillar, mermaid, and even the term "waltzed" has been used, though not with much actual association with Terpsichore

Severe jaw injuries, such as gunshot wounds that require bone grafting are often best repaired with a permanent pedicle flap The flap is usually available lower down on the neck (Fig 91) and is moved up on two pedicles left permanently attached This provides a good minute blood supply in the bed for the bone graft and also excellent coverage for it, being definitely superior to parasitic flaps let in from a distance The neck defect can be grafted at the same time or later, with good function and smoothness often resulting

Skull, scalp, and forehead defects are often best covered with a permanent pedicle blood-carrying flap (Figs 92, 93, 227 and 267) If it is thought that a necrotic area in the skull may involve both tables, it is best to have the flap ready to put down for coverage before the dead bone is removed In many instances the flap can be designed as a direct one, with the temporal artery in the pedicle (Figs 92 and 93), so that the débridement and the coverage can be done in one operation, in other instances, it may be necessary to design a delayed flap which is prepared in stages

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13

Composite Free Grafts of Skin and Cartilage

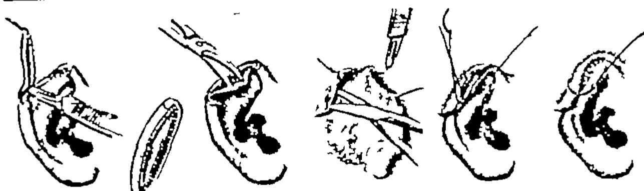
TECHNIC AND USES

These are free grafts, usually taken from the ear and applied to defects of the nose. They ordinarily consist of two thicknesses of skin, with a layer of cartilage in between (though "flat" composite grafts consist of only one layer of skin plus one layer of cartilage).

A composite graft has sufficient rigidity, thinness and sharpness of contour to make an excellent nostril border, or even most of an entire nostril, and is invaluable for filling in full-thickness defects of the nostril. The result is vastly superior to that which could be obtained from any type of flap (Fig. 96). In repairing a nostril defect, the edges are pared back to an area where there is rea-



FIG. 96. Composite graft from ear to nose. *(Left)* Basal cell carcinoma, involving full thickness of ala. *(Right)* Result of one operation for wide excision, and filling defect with free composite graft of cartilage and two surfaces of skin, taken from ear. Nostril repairs with composite grafts are usually superior to any others known.



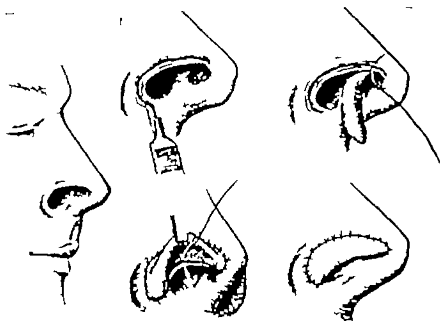


Fig 97 Sketches of the operative details of transferring a composite graft of cartilage and two thicknesses of skin from the rim of the ear to the nostril border Single operation on the nose. Raw area on the ear buried beneath postauricular skin at the same operation and released about 10 days later with enough skin attached to it to complete repair of the ear (Brown J B and Cannon Bradford Composite free grafts of two surfaces of skin and cartilage from the ear, Ann Surg 124 1101)

sonable thickness and a good minute blood supply A pattern of the defect is cut out of celluloid (bleached x ray film), lead, or other material Then the ear is flattened out and examined to determine where a graft nearest the shape and the size of the pattern can be removed and an inconspicuous repair of the ear is carried out

Often the crus of the helix is the best choice. After a graft is excised from this area, the edges can usually be beveled to a gradual slope and the anterior skin sutured to the posterior skin the loss of the thickness of the crus is scarcely noticeable

Sometimes a wedge (with the base on the rim) is taken out of the upper posterior segment of the ear A V-closure can be done, with slight shortening of the ear but not very noticeable if the graft is not too large.

Occasionally a long segment is taken off the helix in the superior posterior area of the ear The edges of such a defect can be trimmed to a gradual slope, the skin over the back of the ear and the postauricular sulcus undermined and advanced so that it can be folded double to make a new helix to fill the defect. This results in a slight decrease in the depth of the postauricular sulcus but usually is not noticeable

After the donor area for the graft is chosen it is flattened out, the pattern laid on it, and traced with a mechanical drawing pen and 5 per cent alcoholic methylene blue A field block around the graft can be done with procaine but no solution is injected within the graft. A fine suture or two can be passed through the graft and left long for holding the graft so that no forceps are used

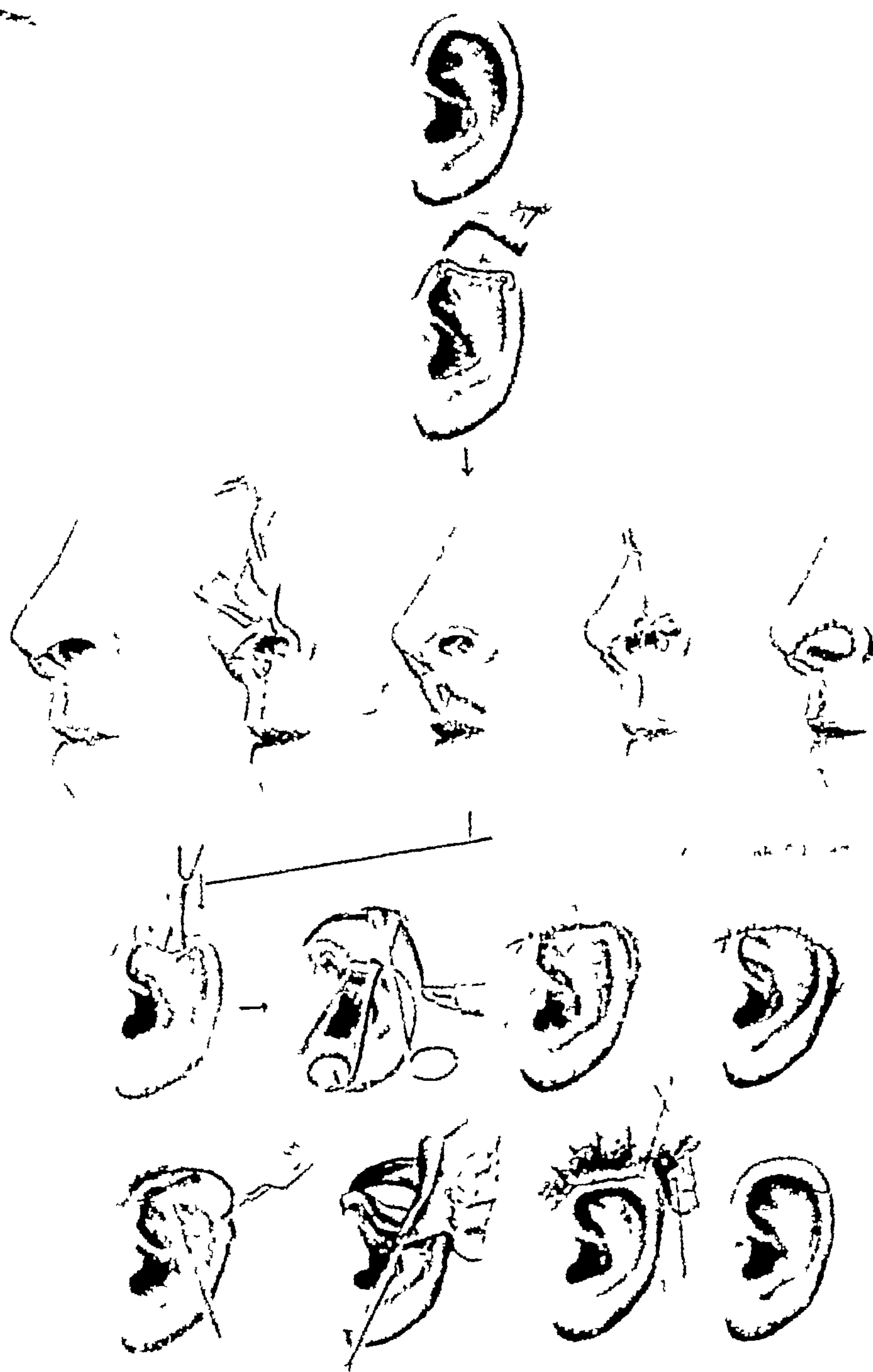


FIG 98 Reconstruction of ala angle and columella with a single composite free graft in one single operation. Secondary freeing of the ear from the scalp with a split graft, in this instance The patient is also shown in Figure 99 (Brown J B, and Cannon, Bradford Composite free grafts of two surfaces of skin and cartilage from the ear Ann Surg 124 1101)

on it The graft is cut with a stab blade (No 11) knife with a sawing motion, through the complete thickness of the ear The ear is repaired as outlined above (Figs 97 98).

The two ends of the graft are fastened in place with fine, interrupted sutures, being certain to have the convex surface of the graft outward Following this, the graft is anchored with multiple interrupted 000000 black silk sutures put in about 1 or 2 mm apart, and not more than 1 mm wide, inside and outside The graft is never grasped with a forcep, or crushed in any manner.

The whiteness of the graft is so extreme at this stage as to be very upsetting, until the surgeon has done enough of them to be used to it

The graft is now covered, inside and outside, with a sheet of fine mesh grease gauze,



FIG 99 Restoration of ala angle and columella in one operation by a free composite graft from the ear The ear is shown after later detachment from the head by a split graft (Brown J B and Cannon, Bradford Composite free grafts of two surfaces of skin and cartilage from the ear Ann Surg. 124 1101)

The inside of the nose (both nostrils) is packed firmly (but not distended) with iodoform gauze A thin layer of fluffed surgical waste is placed over the outside of the nose and an external aluminum splint (usually with a forehead attachment) is applied and molded in to make uniform but gentle pressure over the entire nose and graft Narrow strips of tape or Elastoplast are strapped across the bottom of the nose for gentle pressure in this area

These grafts can be lost from failure of arterial blood to get into them or from venous congestion with failure of blood to drain out If the rims of the defect are pared back to an adequate blood supply (and this may be impossible in some radiated noses) and if the pressure dressing is not too tight blood should enter them on about the 2nd day and the supply be well established by the 4th day The clinical evidence of this is a uniform pink color with blanching and return on pressure (the 'flash' test) During the first two days, the grafts have to survive by lateral osmosis so that no portion of the graft should be more than 1 cm from its

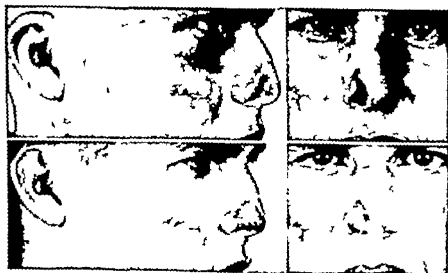


FIG 100 Large replacement of nostril defect by use of a free composite graft of skin and cartilage in a single operation Minimal ear deformity with scalp flap restoration (Brown J B and Cannon Bradford Composite free grafts of skin and cartilage from the ear Surg. Gynec. & Obst 82 253 255)

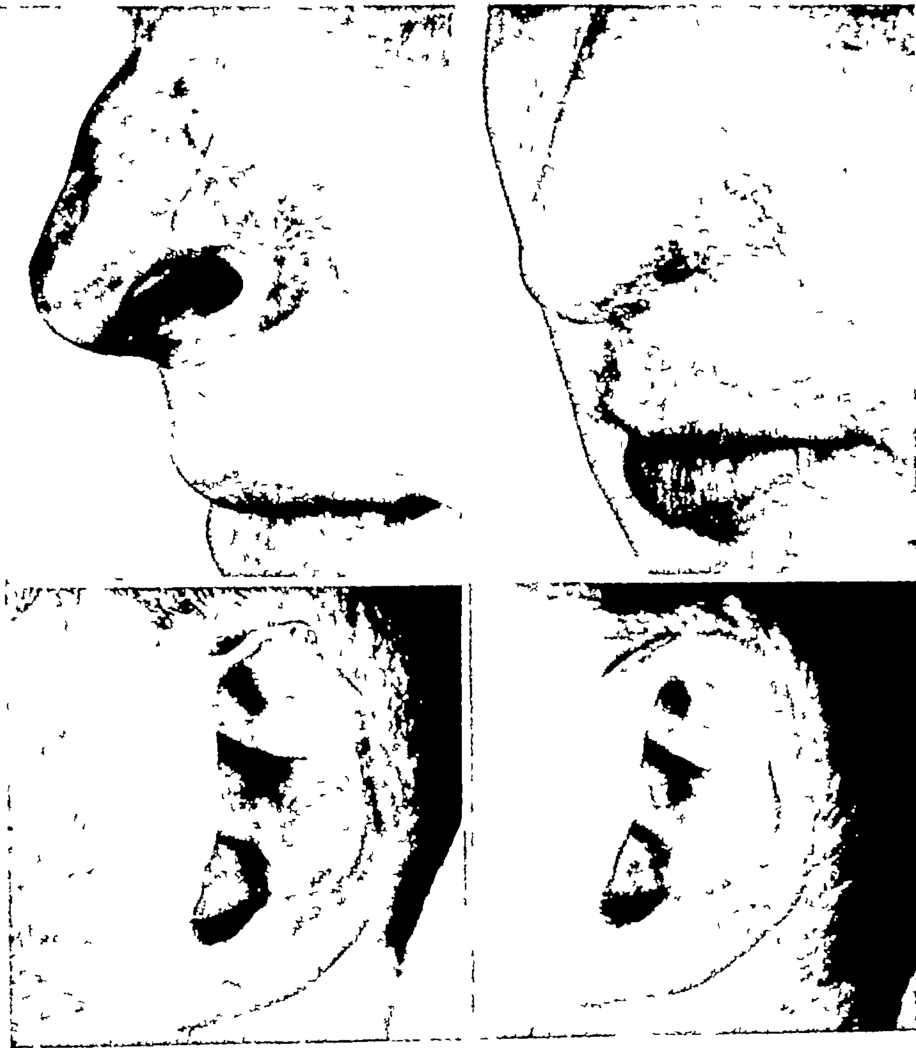


Fig 101 Total resurfacing of burned nose in a single operation with a full-thickness graft from above the clavicle Reconstruction of both alae later with free composite grafts from the ear at one operation Bottom photographs show the burned ear which was used for the alar reconstruction and repair of the ear after removal of the graft (Brown, J B, and Cannon, Bradford Composite free grafts of two surfaces of skin and cartilage from the ear, Ann Surg 124 1101)



Fig 102 Large nasal restoration in a single operation with a large composite free graft from the ear (Brown, J B, and Cannon, Bradford Composite free grafts of two surfaces of skin and cartilage from the ear, Ann Surg 124 1106)

nearest blood supply, this limits the size of the graft A good gentle pressure dressing is helpful in preventing cyanosis and venous congestion, and in keeping the area clean and preventing infection Composite grafts can be done successfully without a dressing, but the percentage of successful "takes" will be much higher if the detail of a good dressing is attended to meticulously.

There are probably few other places in



FIG 103 Successive composite grafts to fill large nasal defect. (*Left*) Upper border of defect was a thin scar wall for some distance up After excision of scar upward to normal bleeding tissue the defect was too large for a single graft. (*Center*) Result of first composite graft from rim of left ear (*Right*) Result after second composite graft from right ear was inserted below the first graft. This was done about two months later



FIG 104 Flat composite graft. Excision of carcinoma of nose (*left*) all around down through cartilages to lining (*Right*) Immediate filling of defect with flat composite graft of cartilage and one layer of skin from back of the ear

surgery where preciseness in technic or attention to details so definitely spells the success or the failure of the operation but routine success can be expected if these are carried out (Figs. 99 100 101 and 102)

MULTIPLE COMPOSITE GRAFTS

As noted before a single composite graft is limited in size to 1 cm in its shortest dimension However in large full thickness defects of the ala and the side of the nose a composite graft of this size can be applied superiorly in one operation, and a second graft placed inferior to it after 2 or 3 months Similarly in expanding a diminished or contracted nostril, a wedge composite graft 1 cm wide at the base (nostril rim) can be inserted vertically at one operation and another wedge later at a second operation By this 2-stage technic (securing one graft from each ear) very sizable defects of the lateral wall of the nose can be repaired successfully (Fig 103)

FLAT COMPOSITE GRAFTS

Patients will be seen with carcinomas or other lesions involving the skin and the cartilage over the lower nose but with the

lining not involved Formerly, these patients usually had full-thickness resections of large areas of the nose, with subsequent flap repairs

Now, it is possible to excise these lesions down to the lining and immediately fill in the defect with a "flat" composite graft consisting of one layer of skin and one layer of cartilage (Fig 104) These grafts are usually taken from the back of the concha, and it helps in taking them to inject procaine between the anterior skin and the conchal cartilage The defect on the back of the ear is covered by undermining and advancing postauricular skin, or by a free graft from the back of the opposite ear

SUBSEQUENT DRESSINGS OF COMPOSITE GRAFTS

The first dressing is usually done on the 4th day After careful but thorough cleansing, the same type of dressing is reapplied with the same careful attention to details and is changed about every 2nd day The sutures can be removed in about 10 days, and the dressing left off then, or a day or two later

MISCELLANEOUS USES OF COMPOSITE GRAFTS

A composite graft can be used occasionally to replace a missing rim or other portion of an eyelid in an anophthalmic socket Since the lining will be skin in an ordinary composite graft, it should not be used in front of a seeing eye However, if conjunctival lining is available, flat composite grafts could be used in some of these instances

Columellar repairs are always difficult and frequently are carried out best by means of one or more composite grafts

Minor ear losses, especially rim segments, can be repaired with composite grafts from the opposite ear

For replacement of tiny losses in only the wide fleshy part of the nostril base, a small soft composite graft can be used from the other nostril base or from a wedge out of an ear lobe These do not contain cartilage, are rather flabby and shapeless and are not suited for repairs out on the main thin segment of the nostril rim

With further research and experimentation, other uses, and even other donor areas, will doubtless be proved, extending the great value of composite grafting

14

Contractures

In the repair of late burn contractures free skin grafts can be used extensively and will give permanent bearing surfaces in many instances They often may be substituted for a tedious use of pedicle flaps that would require multiple operations

AVOIDANCE OF CONTRACTURES

Contraction of the wound edges is part of the normal healing process and attempts to combat it with splints or countertraction usually are of no avail they may produce tears in the granulations with bleeding exposure of deep structures and subsequent contractures of even greater severity One patient has been seen who had the flexor tendons at the wrist sawed through with a bandage by attempts elsewhere at counter traction to prevent an axillary contracture. The use of plaster casts or 'wedging plasters is apt to result in pressure sores or necrosis of the areas on which the counter pressure is applied without preventing the contracture The best preventive seems to be early grafting to stop this wound stimulus but even then some secondary openings with insertion of more skin may be necessary

GENERAL PRINCIPLES OF REPAIR

If any considerable amount of raw surface is present with the contracture it may be advisable to cover this at the first operation and to relieve the deformity subsequently

When sinuses extend down into scar folds and harbor organisms detrimental to the chance of "take of a skin graft it may advisable to do a preliminary opening a excision of these followed by a short peri of wet dressings and subsequent skin gra ing (Fig 130) In the grafting of all co taminated open wounds, the thick split gr is used instead of a full thickness one b cause of the greater assurance of its 'tak in such a field

If the late contracture is healed so that clean operation can be done then the u of a full thickness graft can be undertak much more safely but even here in ma instances, the split graft can be used sat factorily and may even be required if t area to be grafted is so large that the nec sary amount of full thickness skin cann be sacrificed

In repairing healed contractures all su rounding skin possible is utilized, and a webs present may also be fashioned in local flaps ("Z" plasties etc.) and used the contracture is very marked and compl relief is to be obtained, there usually w be a considerable amount of raw surfa to be skin grafted even after all availa local tissue is utilized This grafting is us ally done at the same operation

In opening contractures caution is a visable as important structures may pulled out into the scar Care must be tak to avoid severing any important vessels nerves and exposing tendons joints, bones If the scar is broad and dense witho any appreciable webbing it may be b first to excise the superficial layers of Then the deeper portions can be dealt w

by gradual decortication (removing it in thin layers), or by opening transversely across it at many different points, or by a combination of these Constant but light traction is made during the process, and various tight points in the deep scar can be palpated and opened as they appear However, any strong or sudden jerking movements may cause undesirable exposure of deeper structures Sometimes the skin edges can be pushed back for considerable distances with a piece of gauze

Darts in the surrounding normal skin may be necessary if the contracture is long-standing (Fig 105) The contraction develops in all directions, consequently, corresponding opening cuts may be necessary The opening usually should be continued until complete relief is obtained, e g, in an axilla so that the arm can be extended upward until it touches the head, and in the neck until the head can be extended backward The raw surface remaining for grafting usually consists of short strands of scar and fat If a tiny area of any important structure is exposed, this dissection is stopped at that point, and a small local flap of fat is sutured over it The dissection is resumed in other places Muscles may be exposed during the process, but one rarely has to cut into them However, in one old axillary contracture it was necessary to advance the pectoralis major on the thoracic wall before obtaining complete extension (Fig 130)

The bow-stringing of vessels and nerves across the contracture is an uncommon but most troublesome complication It is most apt to occur in old contractures about the elbow or the knee Everything else in the area is made as free as possible, and then the surface is covered with grafts Either splinting or light traction is utilized to maintain the degree of opening, after 3 or 4 weeks, when the grafts are stable, either extra traction or exercises can be used to help stretch them Secondary opening and grafting after this may be necessary At times it may be best not to do the grafting primarily but to use traction and moist dressings for a few days after the opening and then graft (Fig 152)

Bony dislocations may occur in severe contractures of long duration, but usually they can be reduced, after the soft tissues are opened, without special equipment or great difficulty (Fig 215) Secondary shortening of tendons and joint capsules can be quite troublesome about the hand and is discussed under repairs pertaining to that region

Physiotherapy and directed exercises may be quite helpful in regaining function after the grafts are stable (Fig 106).



Fig. 105 The use of darts in opening contractures (A) Axillary contracture with scarring from elbow to axilla to below hip (B) Type of dressing used after grafting (C) Complete function is apparent (notice the darts). (Surg., Gynec. & Obst 60·379)

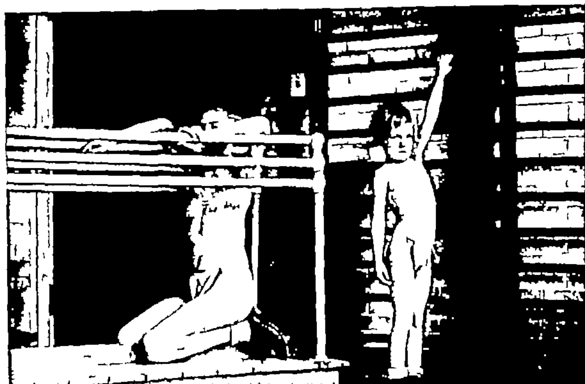


Fig 106 Simple equipment which is useful in working out postoperative stiffness or even secondary contractures Even a trapeze hung in the transom of the hospital or the home may suffice. The instillation of a will to help himself in the patient may be more important than the type of equipment Massage baking and baths are seldom necessary if the restoration has been adequate and the patient is able to exercise (Surg., Gynec. & Obst 56 790)

"Z" PLASTIES AND OTHER LOCAL FLAPS

In old cases in which the scar has been drawn out into a web and there is little or no deformity, occasionally it is possible to effect the repair by using the web itself This is commonly called a "Z" or reversed "Z" plasty however, the openings seldom actually resemble a "Z," and the main point to remember is that the two surfaces of the web are saved and fitted across each other to obliterate the web (Figs 107 and 108)

Other types of local flaps include the double Z plasty "V Y" procedures turning "U flaps into inverted "T" incisions



Fig 107 "Z" plasty for a webbed burn scar of the neck in which the jaw was not down pulled down very badly This procedure may be useful for eliminating webbing when there is not much limitation of motion. It does not replace lost skin but changes the axis of tension.

etc The fundamental principle of all of these procedures is that they do not create any more skin but only change the axis of the skin tension If the skin is moderately tight in one direction but fairly loose in an axis transverse to that, any of these procedures may be helpful They are more useful in the repair of congenital webs than in burns However, in some burn contractures, the use of adjacent flaps or the two surfaces of a web may be combined with free skin grafts to cover the opening Scar flaps should not be too large because their blood supply may be extremely uncertain

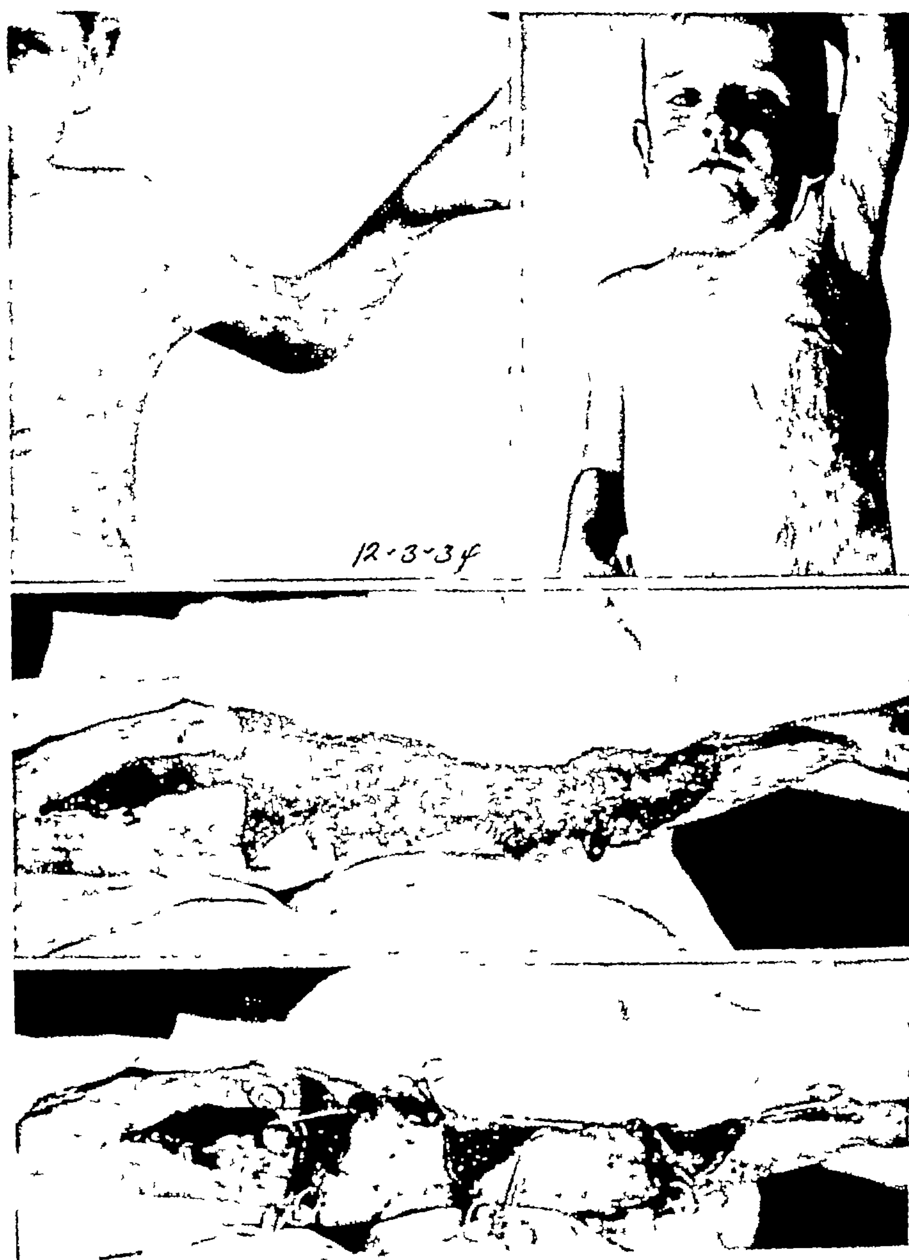


FIG 108 (*Top, left*) Webbing of axilla but also contracture, so that it is known that some grafts will be necessary. (*Top, right*) Result of single operation, complete function (*Center*) Method of opening a webbed area splitting the two surfaces in two, loosening and replacing surrounding tissue (*Bottom*) Fashioning flaps of the web in various shapes and leaving open areas to be covered with split grafts (Clinics 1·25)



FIG 109 (*Left*) Generalized skin shortening No gross deformity is evident except scarred areas over back buttocks and thighs so tight that the patient had not been able to sit down normally for 26 years. The patient was a chronic invalid, and chordotomy had been contemplated in another hospital Multiple areas over back and buttocks were opened and spread and split skin grafts were inserted (*Right*) After 15 years duration of function (Surg, Gynec. & Obst 72 848)

GENERALIZED SKIN SHORTENING

Generalized skin shortening is a term applied to areas that have healed possibly with satisfactory surface, which show no gross deformity but do not permit normal function of complete flexion and extension This is due to deep scarring and insufficient skin and is comparable with clothes that are too tight—the patient simply cannot bend around in his envelope of skin The situation becomes especially bad if he puts on weight, as the dense blanket of scar will not distend for the new fat and at times this thick unyielding surface actually seems to form bursae over the deep fat. Notable examples of this have been seen One patient could not raise her arm without raising her leg (Fig 105) and another had not sat down normally for 26 years (Fig 109) The repair consists of opening suitable areas either stretching back the edges or removing scar that is too dense, and filling the defect with free skin grafts.

15

Repairs of the Hands

COMMON PROBLEMS IN HAND REPAIRS

The hand is one of the most extraordinary and delicate mechanisms in the human body Along with injuries to the covering, there may occur serious or even irreparable damage to the deeper structures If the hand is to function satisfactorily after replacement of the covering, it is important to retain or regain suppleness of the joints, gliding of the tendons, solidity of the bones, sensory function of the nerves, motor function of the intrinsic muscles, and adequate circulation throughout Lack of any one or more of these can impair or even negate the final result but should not stop the most vigorous efforts to achieve the best possible ultimate function Amputative procedures are often the quickest and easiest way out, but are quite final and should not be resorted to when there is any equivocation or until other possibilities have been ruled out or exhausted

Every surgeon working with hands should realize that maintenance of the position of function is basic, with it, no matter what else happens, probably some use will be retained in the hand, without it no matter what else happens, the hand may end up completely useless This position is with the wrist dorsiflexed (or extended), the fingers and the thumb in moderate flexion at all joints, and with the thumb around in front of the fingers, opposing them It has been likened to grasping a ball, with the wrist extended The Mason-Allen universal hand splint (made of aluminum) is very useful for maintaining this position.

The second great problem is that of retaining suppleness of the finger joints The crux of this problem is that immobilization of finger joints in patients over 30 years of age, even for 2 or 3 weeks, may result in more or less permanent stiffness of the joints This immobilization may be from splints, bandages, casts, scar, edema, burn membranes, or voluntary from extreme pain of open wounds, but whatever the cause, the end result is the same To prevent this, every few days from the beginning, fixation should be removed and the finger joints gently and slowly moved through most of the normal range, anesthesia is seldom necessary but is used if it is demanded Cortisone and its derivatives, with antibiotic coverage, have been used in some of these instances for their effect on joints, they appear to be helpful but are not used in large burns Every effort is also made to minimize edema by pressure dressings and elevation and by measures to prevent and control infection

Prevention is more successful than treatment of stiff finger joints However, if it occurs special spring and elastic contrivances can be used to stretch the joint capsules slowly and flex and extend the joints, and physiotherapy is employed—again as a gradual stretching process rather than by any sudden forceful rupturing Surgical capsulotomies may be quite helpful for the M-P joints but are often of less help in the middle and the end joints Every effort is made, in any event, as good covering and good tendon function are of little avail, if limited by one or more stiff joints

As an aid in description, the digits are

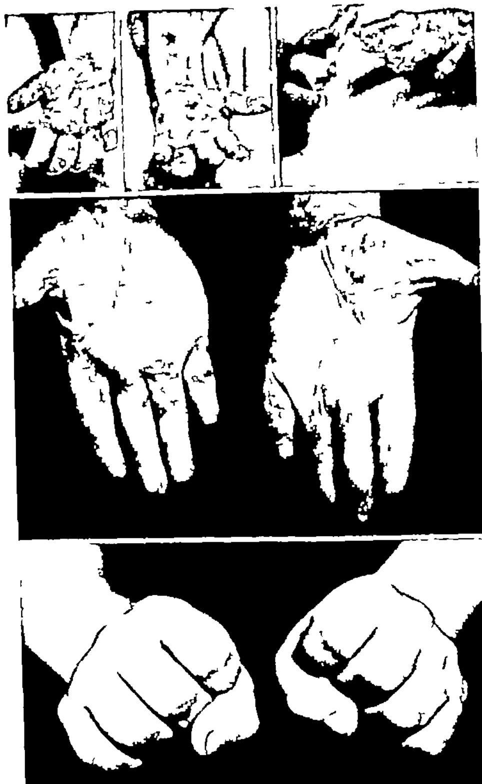


Fig 110 (*Top*) Total burns of hands treated with open surgical drainage and dressed in thick split grafts on the 20th day, avoiding total loss of function (*Center and bottom*) Complete restoration of function and persistence of it after 5 years. (Clinics, 1 25)

usually numbered from 1 to 5 and the finger joints are lettered A, B C from the knuckles out Thus the middle interphalangeal joint of the ring finger would be 4B

GRAFTS VS FLAPS IN HAND REPAIRS

In restoring skin losses on hands free skin grafts will give a superior result to flaps in most instances and always should be considered first (Figs 110-114) Then, if there is some particular reason for not using them or some special indication for a flap the latter may be employed instead

The thinness the flexibility and the resiliency of a skin graft are great advantag in kinesis the graft moves with the ha In contrast, flaps are apt to be thick, bog

and somewhat stiff, the hand tends to move inside this ponderous casing

Epicritic sensation usually develops much more fully in a free graft than it does in a flap

Nevertheless, there are definite indications for flaps especially when thicker coverage is needed for subsequent tendon or bone grafting When such flaps are indicated, it is usually best to get them off the lower anterior chest, where the fat globules are not so large as on the abdomen, and to transfer them as thin as the circulation will permit

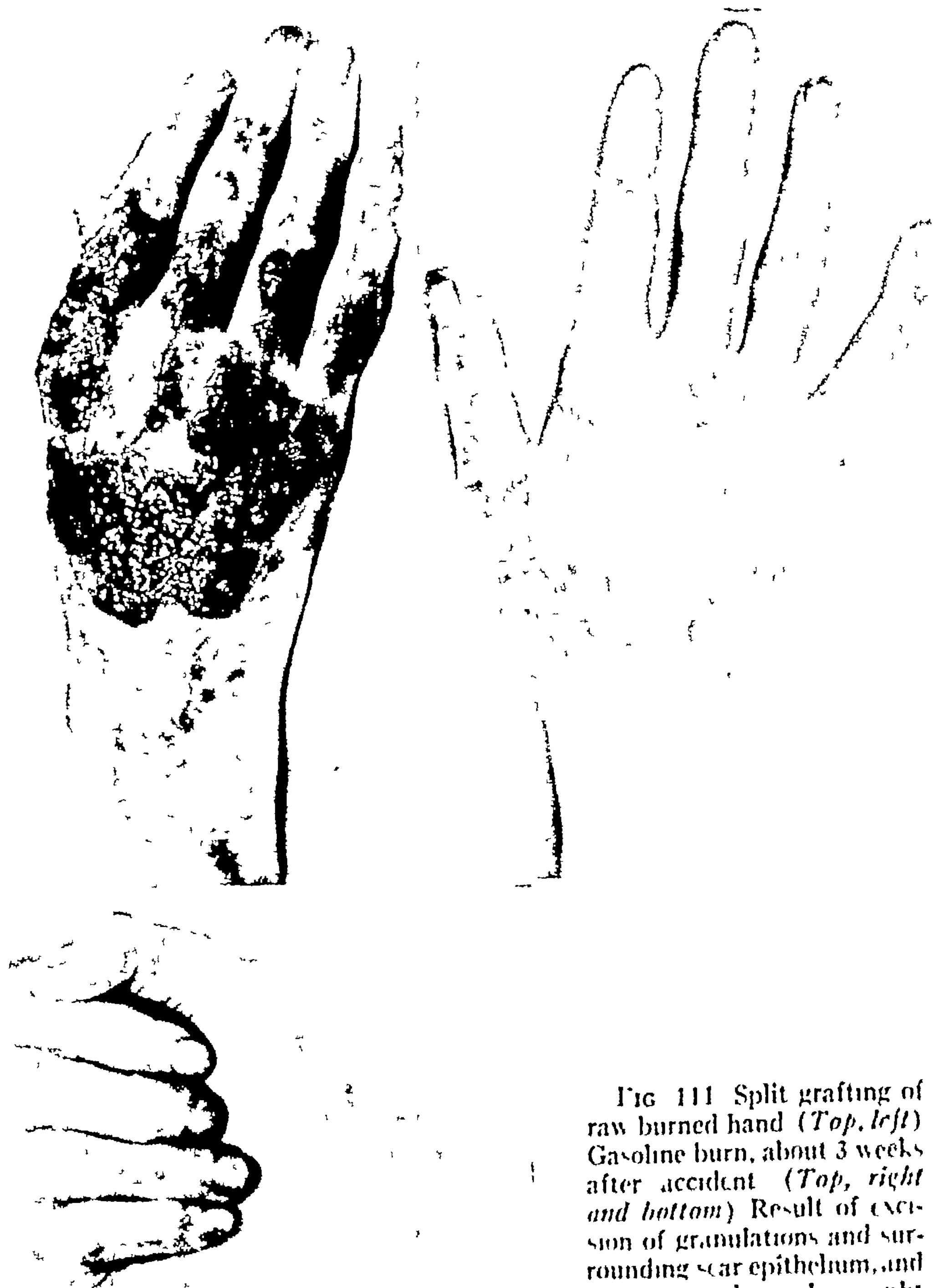


FIG 111 Split grafting of raw burned hand (*Top, left*) Gasoline burn, about 3 weeks after accident (*Top, right and bottom*) Result of excision of granulations and surrounding scar epithelium, and coverage with one large split graft, dividing end of graft for the fingers.

FRESH THERMAL BURNS—THE RAW HAND"

When possible it is desirable to do a surgical débridement of areas of full thickness loss on the hands very early and go ahead with skin grafts immediately or a few days later However it is not desirable to uncover bare tendons or open joints on the dorsum of the fingers In some burned hands it may be more difficult to delineate the full thickness losses from superficially burned areas during the first day or two—particularly on the palmar surface—and a short delay may be necessary for this reason

Until the hands are grafted, they should have firm pressure dressings in the position of function and elevation to minimize edema The finger joints should be moved gently through their range of motion every few days Every effort is put forth to prevent deep infection that will rapidly fix tendons and joints and produce deformities that may never be overcome The hands may be cleansed under general anesthesia and carefully inspected and palpated for any deep infection that may require incision and drainage As noted before the dead skin is removed as soon as feasible wet dressings are applied and skin grafts are put on as quickly as the bed can be made ready (Figs 110-114)

A tourniquet may be used for the excision and the débridement after which it is then removed and complete hemostasis is obtained before the grafts are applied

Usually it is best to suture skin grafts carefully in place on the hand After grafting the first dressing is usually done on the 5th day and then every day or two afterward but no movements of the fingers are started until the grafts are firmly seated—commonly about the 10th day Once movement is started it is increased rapidly every effort being made to get back as much function as possible within 3 weeks Physiotherapy may be necessary after that However children and young adults are an exception and rarely have much difficulty in this.



FIG 112 Split grafting of raw burned hands (*Top*) Hands raw dirty and completely out of position of function from lack of splinting when first seen These hands are typical of some seen following exposure treatment First step was cleansing and débridement under general anesthesia and splinting in correct position with pressure dressings (*Center and bottom*) Result of coverage in single split-grafting operation Function superior to that which could be obtained by any flap coverage

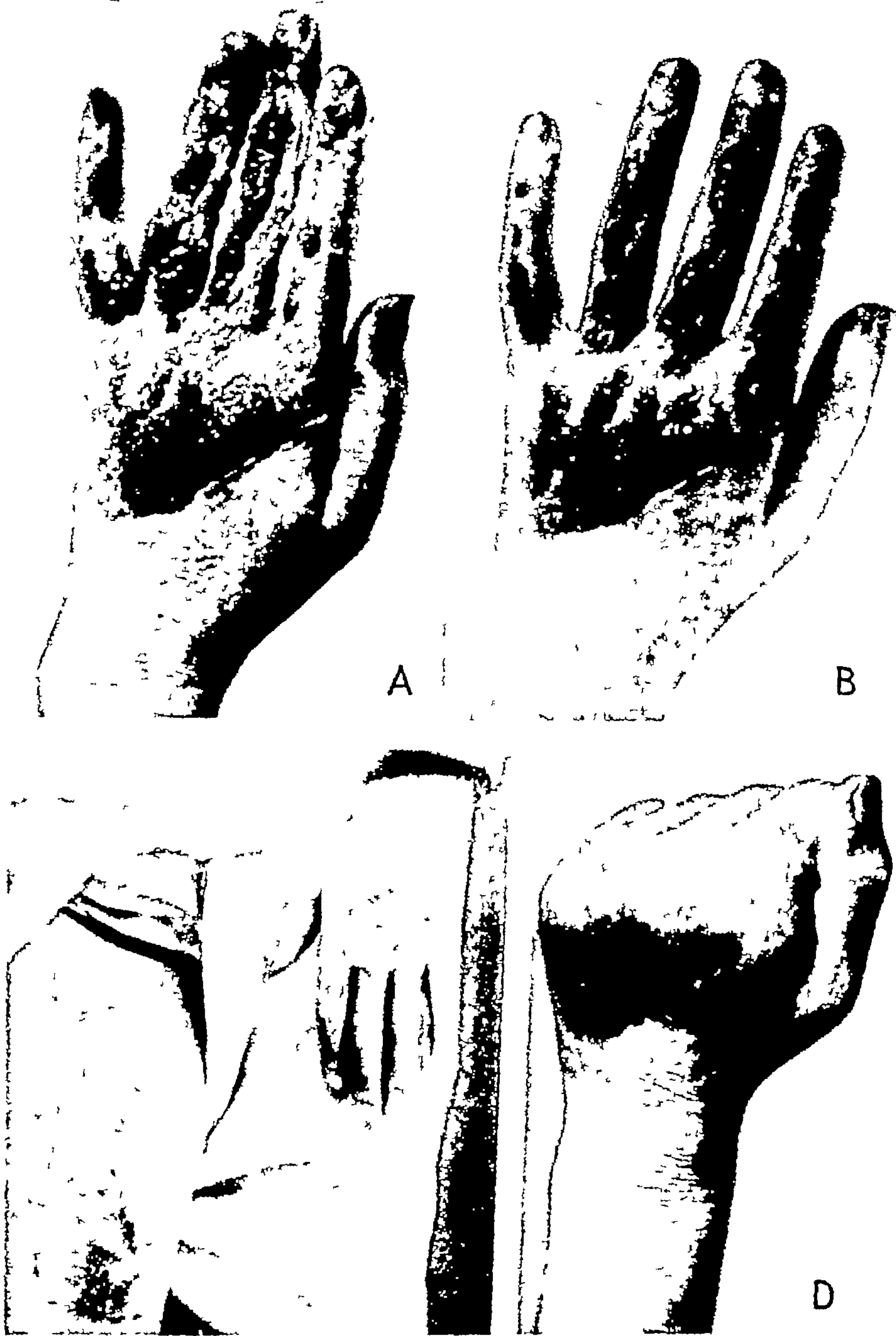


FIG 113. (A) Hand shown 2 weeks after a mangle burn (B) Two days later after saline soaks, gentle débridement and pressure dressing (C) One month later after application of split graft Patient was able to work 1 week later (D) Four months later, showing permanent bearing surface (Surg., Gynec & Obst 60 379)

As a rule, burns of the dorsum are more crippling than those of the palm because of the close approximation of the extensor tendons to the skin surface and to the interphalangeal and metacarpophalangeal joints. A not uncommon type of burn is one in which the mid-portion of the extensor tendon is destroyed over the middle finger joint The most lateral portion of the tendon may slip over on the side, and the patient flexes his finger when he tries to extend

If the patient is burned elsewhere, there may be an unfortunate tendency to neglect the hand, and it may never recover its full function (Fig 119)

There seems to be unanimity of opinion that open surgical drainage is the method of choice in the initial treatment of burned hands that fingers should be dressed apart,

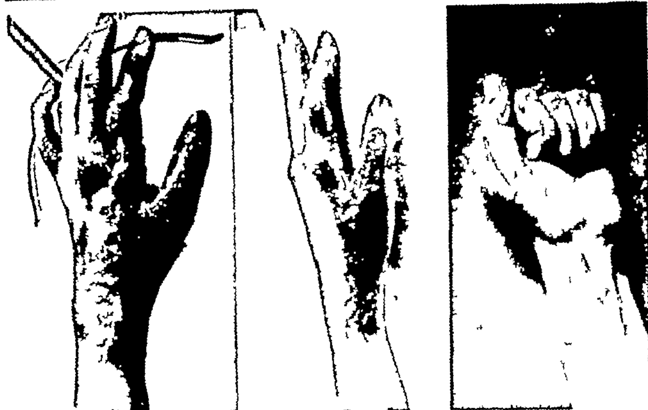


FIG 114 (*Left and center*) Burn of hand shown at time of admission and after a few days of saline soaks and gentle débridement. (*Right*) The patient returned to full time work 5 weeks later after repair with a thick split graft. Result shown after 6 months (South. M J 28 408)

and the whole hand kept in the position of function (Fig 119)

Nearly everyone agrees that the open air treatment or any other sealing membrane treatment has no place in the treatment of burned hands. Instances have been seen where this has been persisted in to the point of deep scar fixation in grotesque positions with the wrist flexed and fingers and thumb extended so that the hand is totally useless except for whatever function can be salvaged by attempts at secondary repair

OLD BURNS—THE SCARRED AND CONTRACTED HAND

As noted before prevention is better than treatment for these but when such patients present themselves, it is usually possible to help them considerably

Late healed deformities of either surface of the hand require extremely careful dissection of the scar to allow complete release without exposing tendons This means that forced manipulations should be done only with great caution to prevent sudden exposure of a wide area of tendon Usually it will be found that the scar can be freed gradually by excision and partial incision through it to allow normal replacement of the parts even though a light film of scar tissue is left on the tendons At this time if it is found that no tendons or only very small areas are exposed a free skin graft can be used Thick split grafts suffice on the dorsum but full thickness grafts are often best on the palmar surface especially on fingers. Some means of fixation should be arranged that can be kept in use for 3 weeks such as the wire screening shown in Figures 115 117 and 118 or aluminum splints prepared before operation as advocated by

Kanavel, Koch and Mason The wire splint is a double thickness of hardware cloth, with the edges covered with adhesive tape The hand and the forearm are laid on gauze padding on the splint, and the forearm is fastened to it with wide strips of sterile adhesive (sterilized in a Formalin cabinet) and a sterile bandage The fingertips are immobilized with small pieces of umbilical tape or, better, with strands of No 24 stainless steel wire passed transversely through them and anchored through the meshes of the screen The wire screen can be bent in any direction to give the desired position to the wrist and the finger joints The hand is usually retained on the splint constantly for 2 to 3 weeks, and then active and passive motion is begun It is particularly important to loosen up the finger joints in older people as quickly as possible If there is any tend-

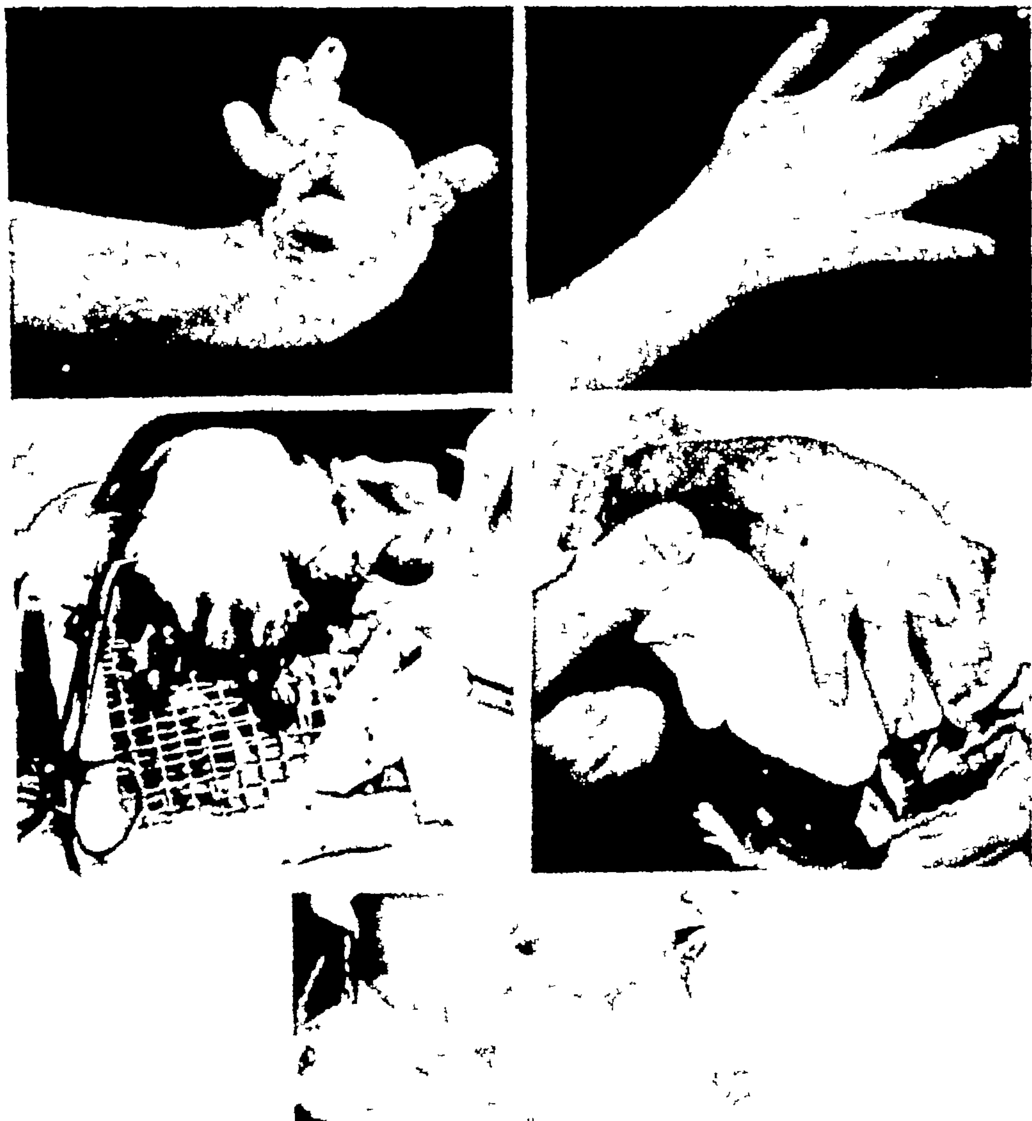


FIG 115 (*Top, left*) Com[illegible] ...ing a wide spread full-thickness loss of sk[illegible] ...ly ou position of func[illegible] (*Top, righ*[illegible] ...er c ful dissection, [illegible] with Method of [illegible] o wire cation of th[illegible] rs of weeks after, [illegible] take (*Bottom*) A [illegible] ...aled

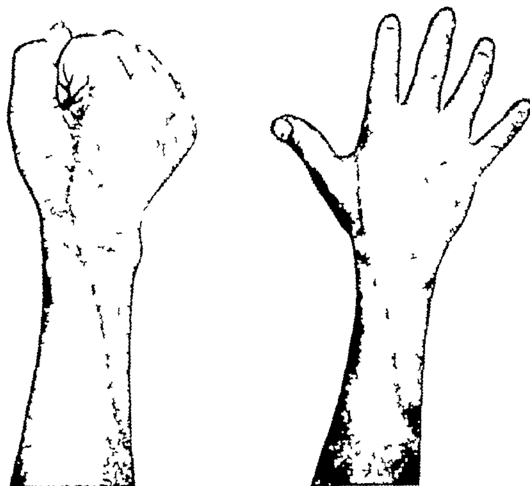


FIG 116 Same patient as in Figure 115 after 6 years with perfect function

ency toward recurrence of the deformity the hand can be immobilized at night for another 3 or 4 weeks on a specially made aluminum splint or one cut out of plywood on a jigsaw (if the neutral position is desired) Children usually need no physiotherapy (Fig 120) but older patients do especially if the burn is on the dorsum and the extensor tendons and if joints have been involved

Burned tendons and bones may be very slow to separate but should not delay the grafting unduly A preliminary débriding operation can be done or definitely dead portions removed at the time of grafting Conservatism is usually worth while as the cortex on one side of a phalanx may separate and later healing may leave a functioning bone (Figs. 255 and 15)

Tendon and joint contractures may prevent complete release of a deformity but can be opened as far as possible and grafted and traction or occasionally tendon lengthenings used later followed by more grafting Some 5th fingers will be seen that are so badly burned and ankylosed that almost nothing is left but a curved stiff bony hook covered with scar epithelium Reconstruction of these is not satisfactory so they should be amputated if they interfere with other hand movements

Partial restoration of function is the best that can be hoped for in some severe injuries but is well worth while (Figs 119 and 121) Possibly many of these deformities might be prevented by adopting the view that the lost skin *should* be replaced early probably there never can be any excuse for the completely webbed or degloved hand as it has been called

Permanent function of free grafts on

Kanavel, Koch and Mason The wire splint is a double thickness of hardware cloth, with the edges covered with adhesive tape The hand and the forearm are laid on gauze padding on the splint, and the forearm is fastened to it with wide strips of sterile adhesive (sterilized in a Formalin cabinet) and a sterile bandage The fingertips are immobilized with small pieces of umbilical tape or, better, with strands of No 24 stainless steel wire passed transversely through them and anchored through the meshes of the screen The wire screen can be bent in any direction to give the desired position to the wrist and the finger joints The hand is usually retained on the splint constantly for 2 to 3 weeks, and then active and passive motion is begun It is particularly important to loosen up the finger joints in older people as quickly as possible If there is any tend-

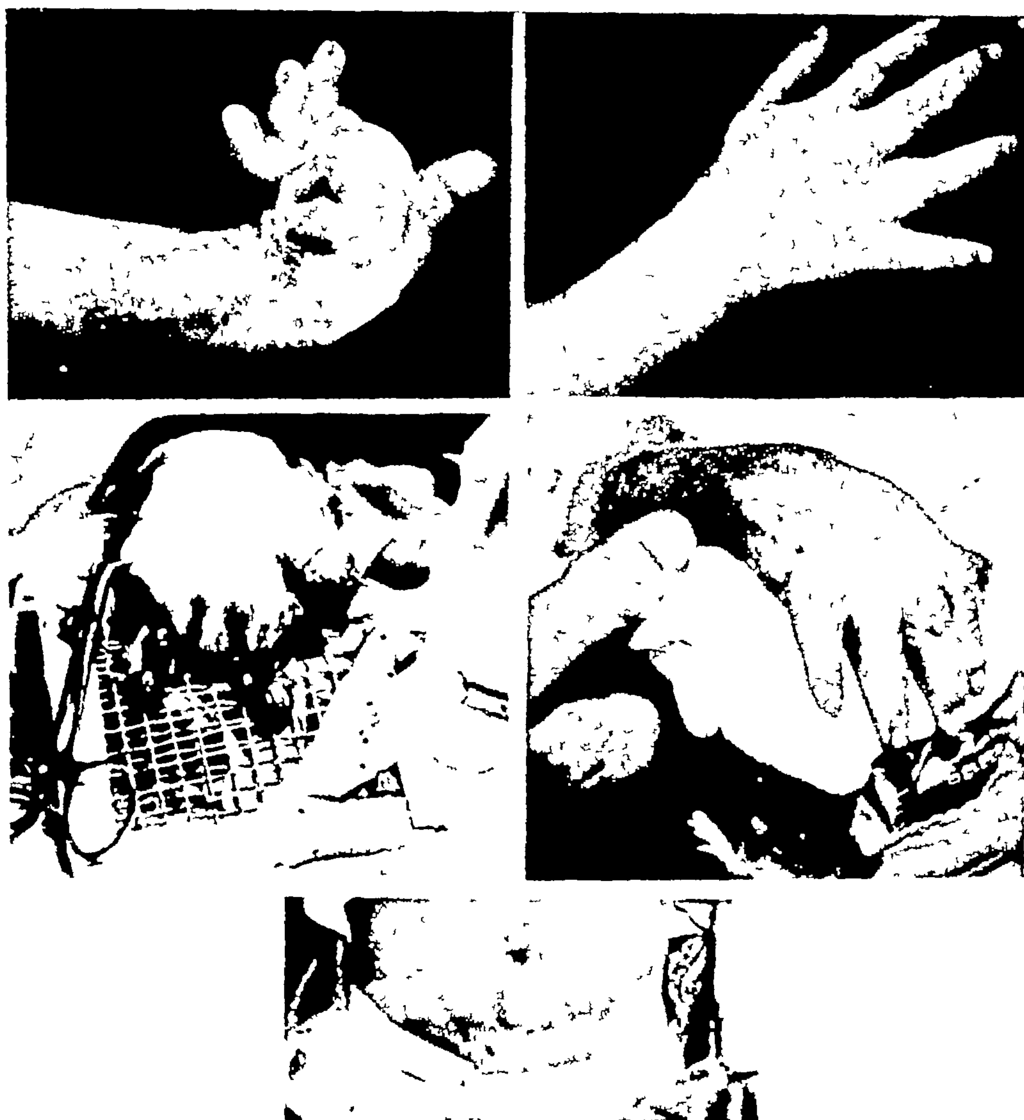


Fig 115 (*Top, left*) Complete extension deformity following a widespread full-thickness loss of skin, with thumb and fingers definitely out of position of function (*Top, right*) Full restoration of function after careful dissection and coverage with a single full-thickness graft (*Center, left*) Method of fastening hand to wire splint with sterile adhesive and of application of the graft (3 hours of operative work) (*Center, right*) Three weeks after operation, full take of graft, arm being taken off splint (*Bottom*) Abdominal defect healed by direct suture (Ann. Surg 107.958)

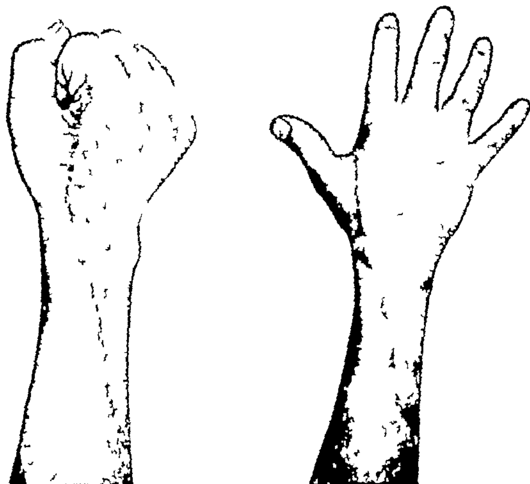


Fig 116 Same patient as in Figure 115 after 6 years with perfect function

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Permanent function of free grafts on

hands has been quite good, and Figure 319 illustrates a total palm replacement done 20 years ago, which has withstood all normal trauma and activity However, the anatomy of the skin and the subcutaneous fat in the palm differs considerably from that of the rest of the body, and such repairs are regarded as usable substitutions rather than true restorations

Pedicle flaps must be considered when too much viable tendon is exposed, or when bones, tendons, or nerves are lost and replacement is being contemplated, though free grafts can be used temporarily for healing in the latter cases The usual flap is a direct one from the abdominal wall, or an abdominal "pocket," which is a direct flap with the pedicle left intact on 2 or 3 sides (Figs 45 and 76)

Replacement of the fingertip pad with a small palmar flap from the thenar or the hypothenar eminence is occasionally of use,

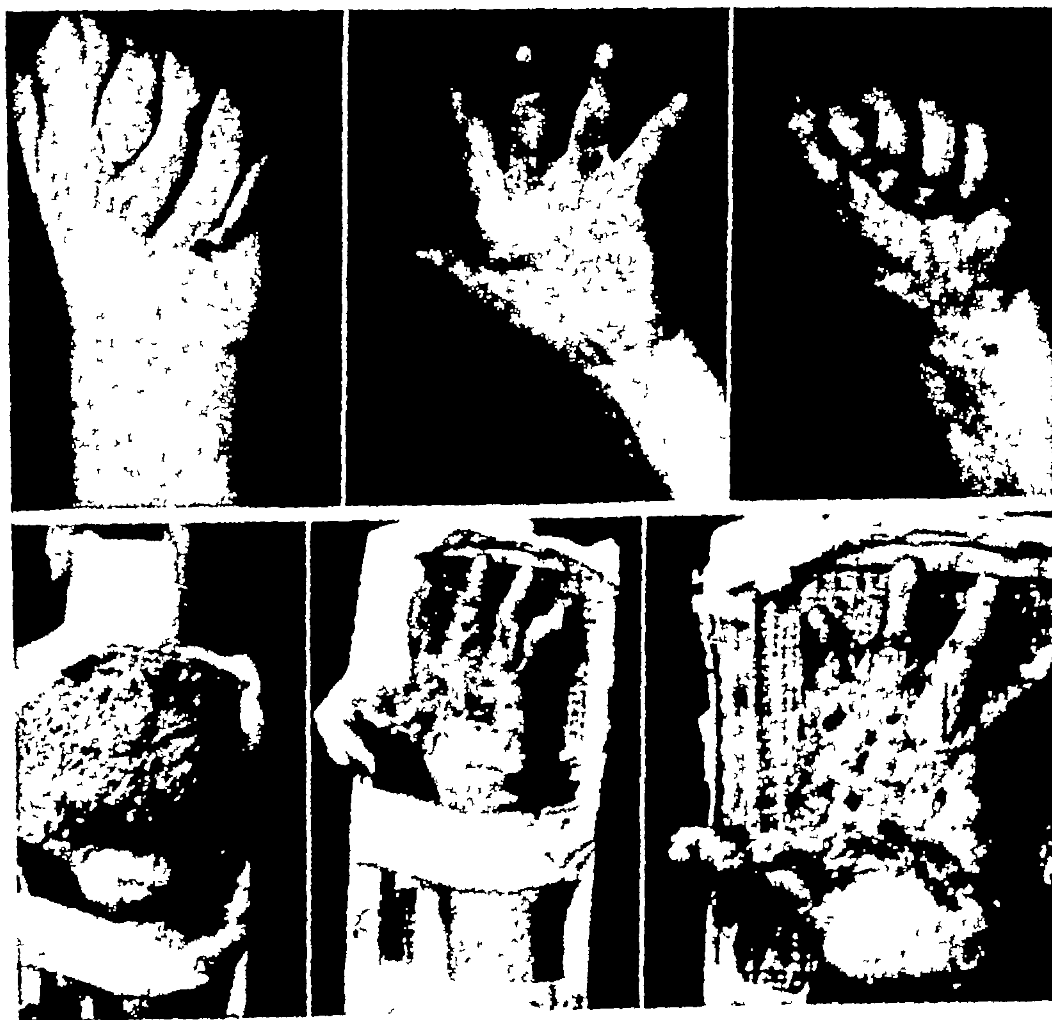


FIG 117 (*Top, left*) Complete flexion deformity and webbing of fingers several years after a burn (*Top, center and right*) Full function obtained with one full-thickness graft and two subsequent procedures to relieve the webbing (*Bottom, left*) Hand shown at time of first dressing with molded marine sponge in place Dorsum well padded (*Bottom, center*) Fine-mesh grease gauze next to the graft, which is dry, indicating full take (*Bottom, right*) Full take shown with edge sutures and individual mattress sutures through the center, fingers held extended with fine wires through each tip and held to the wire splint (Ann Surg. 107:959)

as is a cross-finger flap (Fig 83) The replacement of a fingertip loss with an abdominal flap is to be deplored, as it feels like a ball of jelly to the patient

Cross-finger flaps are obtained from an adjacent finger to cover small deep palmar or deep dorsal losses, where a free graft would not suffice The flap is turned down from the side of the donor finger taking care not to injure the nerves or the vessels in the donor finger The pedicle is on the dorsum or the palm corresponding to the recipient site The donor finger is covered with a free graft the flap sutured in the

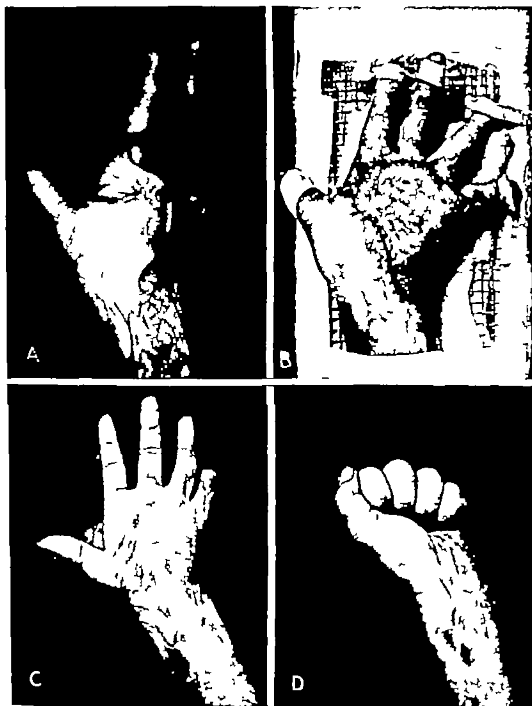


Fig 118 Late contracture of hand due to surface loss without tendon loss. (B) Full-thickness graft restoration after complete freeing of the scar (C and D) Function shown 2 years after the one operation (Internat. Abstr Surg 67 105)

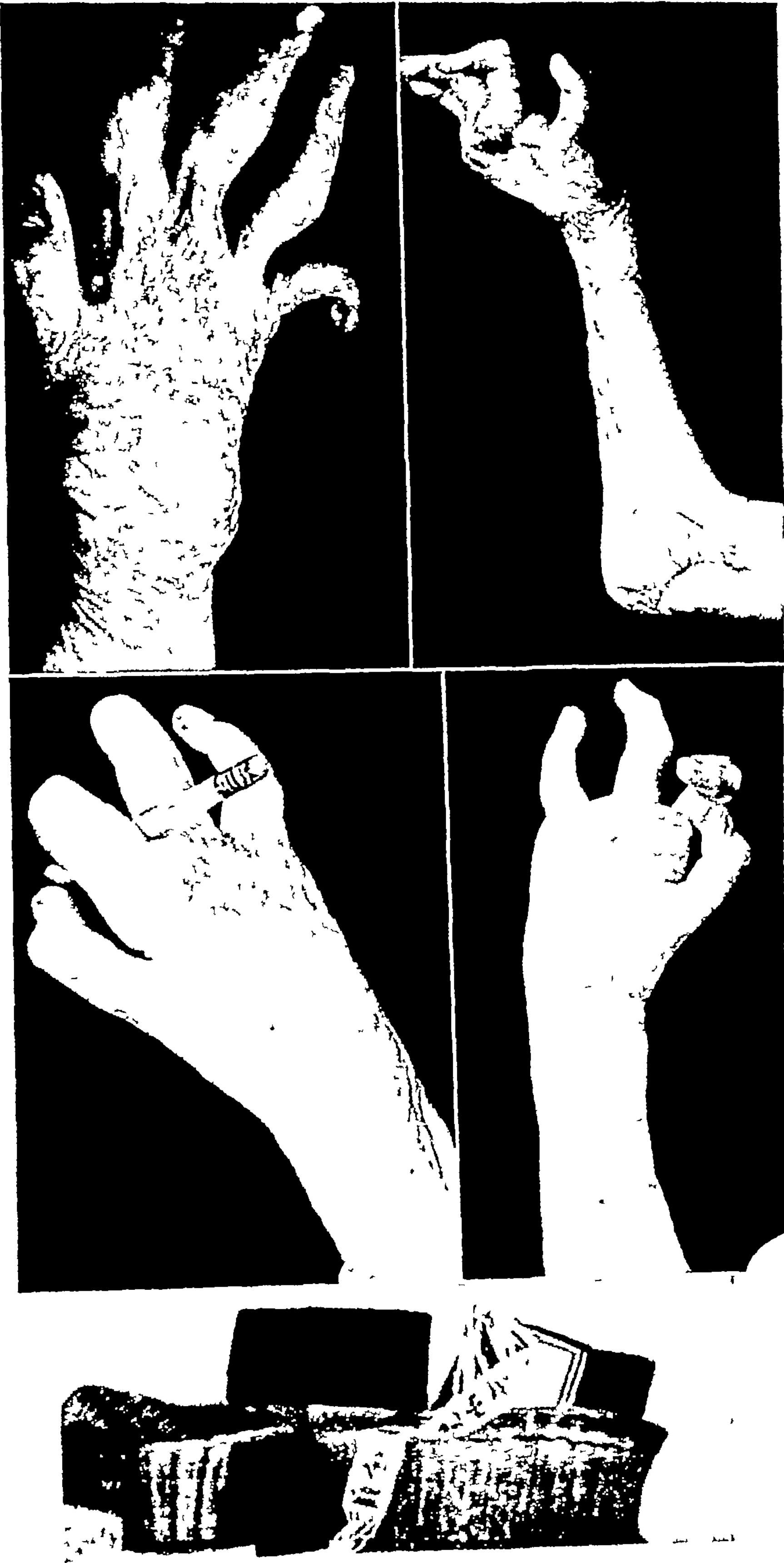


FIG 119 (*Top*) Complete loss of use of hand 1 year after severe burns which have destroyed all the skin and many of the tendons and joints Patient was unable to dress himself (*Center*) After several operations of a rather slow progress in removing the scar and replacing it with split grafts. Appearance not good, but the patient was able to draw well enough to enter art school and do work as shown in bottom part of cut, which includes some of the many objects made as a result of instruction by occupational therapists (Ann Surg 107 956)

recipient area and the two fingers bound together for about 2 weeks until the pedicle is severed and both fingers trimmed and adjusted

Cross-arm flaps are used occasionally for repairing deep losses in the thenar web and eminence The position can be demonstrated best by grasping the opposite arm just above the elbow

OTHER HAND INJURIES

Repairs of other types of hand injuries are described in Chapter 30, "Restoration of Defects from Farm, Traffic and Industrial Injuries," Chapter 31, "Repair of Electrical and Cathode Ray Burns" Chapter 32 'Surgical Repair of Radiation Injuries and Atomic Burns" and Chapter 33, "Skin Grafting in Military Plastic Surgery"



Fig 120 Complete release of severe flexion contracture of baby s hand with one full thickness graft. These nearly always require more skin than one would think In this instance the graft covers half of the palm the entire space between the thumb and the index finger, and extends down onto the thumb and the index finger



Fig. 121 (*Left*) Left hand completely out of position of function 18 months after a deep burn with the arm still not healed (*Right*) Fairly normal position restored by 3 split-graft operations with thumb and fingers functioning for the first time since the burn (Ann. Surg 107 955)



FIG 122 Surgical release of webbed fingers (*Left*) Simple cutting apart of fused normal fingers and coverage of raw areas on adjacent fingers with a single full-thickness or very thick split skin graft. (Cf Figs 123 and 124) (*Center and right*) Flap type of operation sometimes used for separating thumb and index finger A U-shaped flap is raised on the dorsal surface and turned through into an inverted-T incision on the palmar surface, split grafting the remaining raw areas on the sides of the digits. (Cf. Fig 123)

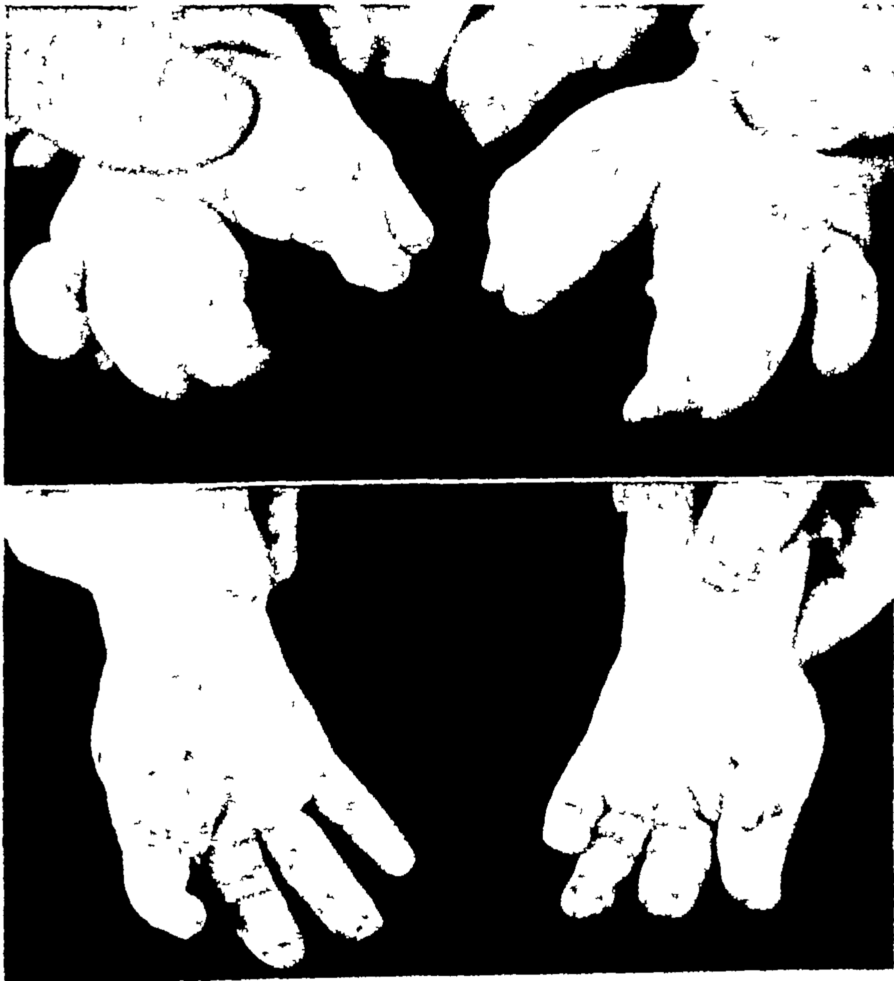


FIG 123 Third and fourth fingers separated as in Figure 122 (A) Thumb and index fingers separated as in Figure 122 (*Center and right*)

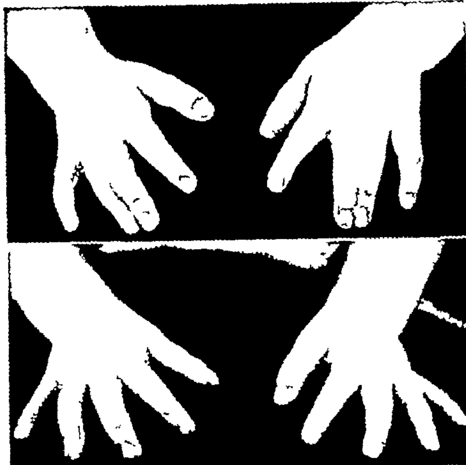


FIG 124 Separation of normal but fused fingers as in Figure 122 (*Left*) Final appearance Function seems to be perfect

WEBBED FINGERS (SYNDACTYLISM)

Early in the embryonic development of the hand it is a flat single, finlike structure and fissures develop later to separate the fingers Partial or complete failure of this fissuring results in congenital webbed fingers. This anomaly may occur in one or both hands (often symmetrical) and may or may not be associated with the same anomaly in the feet When the webbing is confined to one hand an associated absence of the pectoralis major muscle is a rather frequent finding but the latter creates almost no disability and requires no treatment

Webbing may occur in otherwise normal hands or may be associated with an abnormal number of fingers (polydactylism) or abnormalities in the width and the number of phalanges (brachydactylism) In polydactylism the extra digit usually is attached to the metacarpal of the thumb or the 5th finger It is often rudimentary and without functioning tendons but occasionally will be completely developed with good tendons In either event it should be removed in early infancy Ordinarily it is obvious which digit to remove but a few patients will require careful study of the movements, the strength the direction of growth and bony development (as seen on x ray examination) of the duplicate fingers in order to make the correct decision

Complete correction can be obtained in the webbed normal hand with practically perfect results Correction of the webbed brachydactylic hand is well worth while but does not result in perfection Careful x ray and functional studies of the latter are necessary and the plan of treatment must be individualized in each instance

Probably the most common form is symmetrical webbing in two normal hands between the 3rd and the 4th fingers throughout their length (Figs 122 and 124) Operation

on these should be delayed until the patient is 2 or 3 years of age At that time, the depth of the normal fissure between the fingers is marked on both the palmar and the dorsal surfaces (it will be noted that the normal fissure extends farther proximally on the dorsal surface than on the palmar surface, leaving a slanting normal web between the fingers) The fingers are divided with a knife down to these marks, the surgeon being especially careful near the proximal end of the new fissure to avoid injury to any of the proper vessels or nerves The resulting raw surface is covered with a single full-thickness skin graft extending from the tip of the 4th finger down to the sulcus and back out to the tip of the 3rd finger The graft is cut to pattern, carefully sutured in place and fixed by "stent" sutures and an all-over pressure dressing The same plan of repair can be used in full-length webbing between any 2 fingers except between the thumb and the index finger However, it is best to *avoid* operating on both sides of any one finger at one time Thus, if all fingers except the thumb are webbed together, it is better to split the index from the middle finger and the ring from the little finger at one operation, then split the middle from the ring finger at a second operation a few weeks or months later

Webbing between the thumb and the index finger creates special problems because of the disparity in length, the wide range of motion of the thumb, and the normally wider space between these digits (Fig 123) Operation is usually done earlier to allow the index finger to increase in length and to prevent bony curvatures of it from developing An inverted U flap (with the concavity toward the wrist) is raised on the dorsal surface of the web and fitted through into an inverted T incision (with the crossbar nearest the wrist) on the palmar surface This leaves a triangular raw defect on the adjacent side of each digit, and these are covered with thick split grafts (Fig 122)

Occasional patients will be seen with no real webbing but simply fusion of the tips of 2 or more fingers These can be divided in early infancy, closing or grafting the resulting raw spots

Numerous operations for completely webbed fingers have been described in which the raw areas on the fingers are closed with local flaps rather than additional skin (grafts) These result in failure, as there is always a lack of skin, and the resultant flexion deformities produced by them may be more difficult of correction than the original webs

16

Repairs of the Axilla

This area alone accounts for a large number of the burn deformities that are seen and thick split skin grafts in sufficient number offer a simple and almost universally applicable plan of repair

FRESH THERMAL BURNS

In the initial treatment of burns in this region free movement is one of the main objectives and the earlier this can be accomplished the better With the general condition comfort and morale of the patient all being cared for early complete resurfacing of the denuded area will shorten invalidism and lessen or prevent further fixation by the scar that occurs with spontaneous healing

At operation, the granulations are shaved from the areas down to a very thin scar base and some of the full thickness of the scar itself is removed so that complete elevation of the arm is possible (Figs. 125 and 126) Large grafts expedite the work, and they are sewed accurately in place with extra bast ing" sutures through the center A large pressure dressing is applied with the arm up in the 'never again" position (shoulder and elbow at 90° with the hand up in the air) This dressing is made of soft materials consisting of fine-mesh grease gauze, waste abdominal pads gauze rolls, quilted bed pads, additional gauze rolls, bandage and adhesive respectively from inside out and seems to be definitely preferable to a spica plaster cast (Fig 127) Extreme extension of the



FIG. 125 (*Left*) Very large full-thickness loss with secondary contracture (*Center*) Complete healing in 2 split-graft operations and prevention of growth of arm to side after 5 months. (*Right*) Complete function of original repair shown 1½ years later (Internat Abstr Surg 67 105)



FIG. 126. Split grafting of raw burns (*Top*) Clean granulating wounds obtained by débridement and wet dressings Upper extremity burn is circumferential and axilla is burned out (*Bottom, left*) Result a few months after split grafting (*Bottom, right*) Result 8 years later, showing good growth of grafts This boy later became a combat soldier in Korea and was decorated

shoulder (in the dressing) is avoided, as it might produce "stretch paralysis" of the radial nerve

OLD SCAR CONTRACTURES

Contractures of great severity and causing extreme disability may result if spontaneous healing of areas of full-thickness loss is relied on

In relaxing the "arm healed to the side" type, incisions are placed to allow opening of the area with preservation of any flaps possible for covering the apex of the axilla It is well to have one assistant do nothing but hold the arm and gently extend it as the scar gives way. Tightness of the skin from the deltoid region to below the clavicle and over the posterior aspect of the arm must be opened and the defect grafted Even a small triangle of opening is important in these areas and if the graft is successful, this may make the difference between complete and partial freedom of motion (Figs. 128 and 129) Darts into the surrounding normal skin may be necessary if the contracture is an old one, and generalized skin



Fig 127 (*Left*) Plaster-of Paris cast to support arm. This type of fixation is not necessary and may even be detrimental if there is slipping or twisting of the body inside the cast (*Right top and bottom*) Fixation with a folded, quilted, child's bed pad incorporated in the external layers of the dressing This is more comfortable, much more easily applied, and with it the patient can sit up without support and be out of bed The opposite shoulder is not incorporated in the dressing Most of the time, the arm should be supported with extra pillows. The position of the arm shown at bottom, left and right, is preferable to that at top right. (Surg, Gynec. & Obst 56 790)



Fig 128 (*Left*) Total loss of axillary skin and most of right breast by burn. (*Center*) Immediate result after 2 split-graft operations and (*right*) shown after 11-year growth period (Clinics 1.25, 1942)



shortening may extend down to the thigh (Fig 105). The deeper portions of the dissection must be done carefully to avoid injury to important structures, and complete abduction must not involve tearing of underlying muscles In one instance it was necessary to advance the pectoralis major muscle on the chest wall (Fig 130)

"Z" plasties can be used occasionally in

Fig 129 Complete restoration of contracted axilla with thick split grafts in one operation (Surg, Gynec & Obst 56 790)

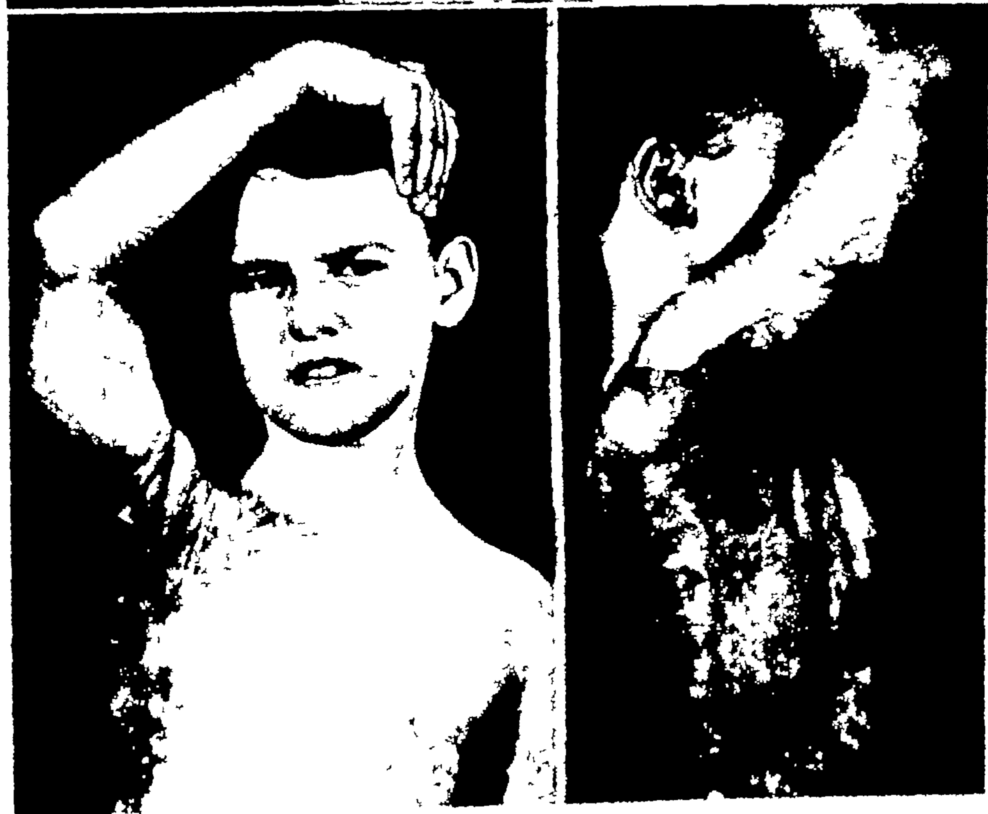




FIG 130 (*Left*) Arm grown solid to body with excessively thick scar and deep dirty sinus extending high into axilla, 2½ years after the burn At the first operation the sinus was opened and cleansing dressings were applied to the raw area At the second operation, the contracture was opened widely, but the arm would not come up satisfactorily In consultation with Dr C H Crego it was decided to advance the pectoralis major and the latissimus dorsi upward on the chest wall, and this was done followed by dressings to the raw area At the third operation (48 hours later) the entire area was covered with thick split grafts (173 sq in) with result shown in the other three pictures. (Surg Gynec. & Obst. 56 790)

cases of long standing with the fixation over a limited area, where the abductor muscles have drawn the scar out into one or more soft webs or plicas which permit free movement In these cases operation is done chiefly to do away with the webbing The fold is split and each side is converted into an appropriate flap by incisions which may somewhat resemble a "Z." There are few patients however, who do not need at least supplementary grafts if immediate and complete function is to be obtained in one or two operations (Fig 108)

Auxiliary flaps from neighboring skin or soft scar are always to be used if possible over the axillary vessels and nerves but extreme care should be taken not to expose the axillary contents during the mobilization In the late healed cases there is usually an increase in the quantity of fat, as happens elsewhere in the body where there is a contracted flexor surface This is a valuable protection to the axillary contents

One criterion of a good result is that the patient should be able to extend his hand directly overhead with the arm up against the head Cases in which the arm can be abducted up no farther than 90° should not be considered as totally satisfactory

Physiotherapy or directed activities may be of value in overcoming postoperative stiffness or even secondary contractures (Fig 106) The instillation of a will in the patient to help himself and the provision of simple equipment for exercise and recreation may be all that is necessary A trapeze hung in a transom of the home or the hospital may suffice Massage, baking and baths are seldom necessary, if the restoration has been adequate and if the patient is able to exercise

BURNED BREASTS

Deep burns in the breast area of young girls may present certain problems The burn may extend just through the nipple area or the entire gland may be destroyed



FIG 131 Burned breasts (*Left*) Child first seen several years after healing by scar, and partial coverage with 'stamp' grafts elsewhere Puberty beginning, and area tight and painful Wide excision of scar done, and coverage with large sheets of split-skin graft (*Center and right*) Result and appearance 4 years later

In the latter event, the initial split graft coverage will suffice permanently, but in the former case, at the time of puberty tenseness may develop and it may be necessary to insert more split graft to allow for expansion and maximum contour development (Fig 131). If the nipple areas are burned off, free lactation will be impossible, but this can be suppressed by hormone therapy after delivery.

GRAFTS VS. FLAPS IN AXILLARY REPAIRS

Burned or contracted axillae may require enormous amounts of new skin for repair, and this is better provided by free grafts than by pedicle flaps Many years ago there was a dictum to use flaps for axillary contractures, and they were routinely unsuccessful—barely getting the arm loose from the chest and not up at all The utility of large split-skin grafts was first demonstrated in massive repairs in this area, and for the first time, such children could swim, play basketball and baseball, and engage in other activities which required the arm to be completely free and go straight up over the head.

17

Repairs of the Arm and the Forearm

Repairs of the arm and the forearm are considered together here, although injuries in these areas are frequently combined with injuries of the hand and the axilla

FRESH THERMAL BURNS

In deep burns here, as elsewhere, the problem is essentially that of getting the slough off and large skin grafts on as quickly as feasible

If not much else of the body is burned often this can be done a few days after the burn, as described in Chapter 5 A tourniquet may be used during the débriding to minimize blood loss.

Long grafts are especially useful when both the arm and the forearm are raw Such grafts can be obtained from the back, starting medial to the scapula coming down over the loin and the buttock and clear on down the back of the thigh to the knee if necessary When cut free hand they can be obtained in widths of 3 or 4 inches if details are observed to flatten out the donor area. These include (1) positioning the arm to flatten the scapula against the back (2) insertion of a hard pillow under the abdomen to elevate and spread out the loin area (3) the use of suction boxes to elevate and flatten out the skin and (4) the use of towel clips in the skin laterally by assistants to pull or push the skin up against the suction box so that full width can be obtained These large grafts are worth the trouble involved as they can be cut in 10 minutes or less and one or two of them will cover an entire upper extremity, with the best possible final cosmetic and functional result

Mangle burns are common in this area especially in children Although there is some crushing along with the burning the repair is done as outlined above The medial and the lateral epicondyles of the humerus and the tip of the olecranon may be burned in such instances, these may be chiseled off to bleeding bone before grafting or after grafting, but should not be permitted to delay coverage unduly (Fig 132)

Burned bone may be large in amount in some patients In such instances soft tissues are prepared and grafted up to the dead bone at an early date Later the dead bone is removed with chisels or otherwise outer cortex or full thickness as necessary and as soon as granulations appear this area is covered with split grafts for temporary coverage If no subsequent bone grafting is necessary the split grafts may be left if serviceable otherwise, the grafts may be removed and a flap substituted—usually a direct flat flap from the chest wall or the abdominal wall on that side (Figs 134, 202, 203 and 266)

Chronic raw arms if circular, may present difficult problems Dense circular scar is laid down in the depths of the granulations constricting the arm and producing edema of the distal parts At operation the

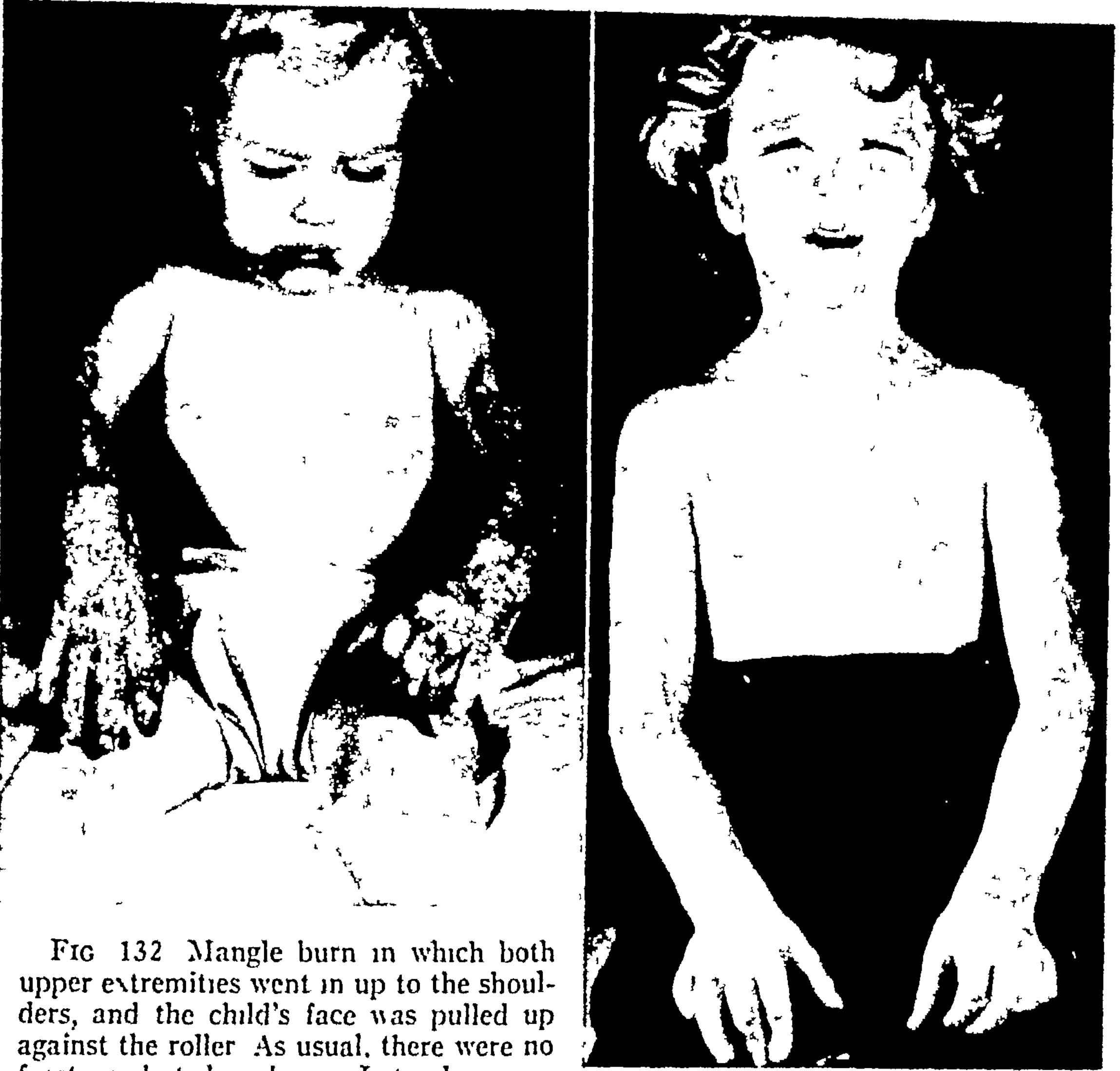


FIG 132 Mangle burn in which both upper extremities went in up to the shoulders, and the child's face was pulled up against the roller As usual, there were no fractures but deep burns Lateral epicondyles of both humeri were burned and separated, as well as central slips of extensor tendons on right middle and index fingers Primary coverage with split grafts Later resurfacing of backs of hands and fingers with full-thickness grafts to get smoother appearance Complete function except in fingers which had burned tendons

granulations are sliced off down to a firm yellow base, and then multiple longitudinal incisions are made down through this base to allow circular expansion, before grafting

Results are usually good when granulating areas are covered early with large thick split-skin grafts The larger and few the grafts, the better the result. Some t ming of border scars may be necessary (Fig. 133).

OLD SCAR CONTRACTURES

With the arm itself, the special poi

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Fig 133 Split grafting of raw burns. (*Top*) Condition when first seen several weeks after fire burns. Treated by débridement pressure dressings and two split grafting operations (*Bottom*) Appearance after 1 year Patient later became a star basketball center

tics at early ages are apparently not very successful but some gains in functional position may be made with wedging plasters and very occasionally with osteotomies Direct flap coverage from the chest wall may be necessary on some of these elbows, following open operation (Fig 134)

However, many of the scar contractures

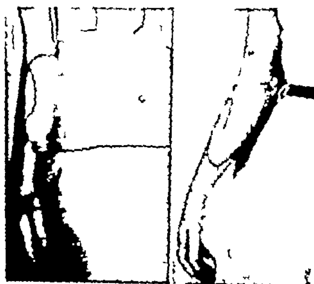


Fig. 134 Direct flap coverage Deep traumatic wound of forearm and ante cubital fossa necessitating putting in flap with arm straight to prevent flexion contracture. Flap on and detached in 18 days. Two operations.

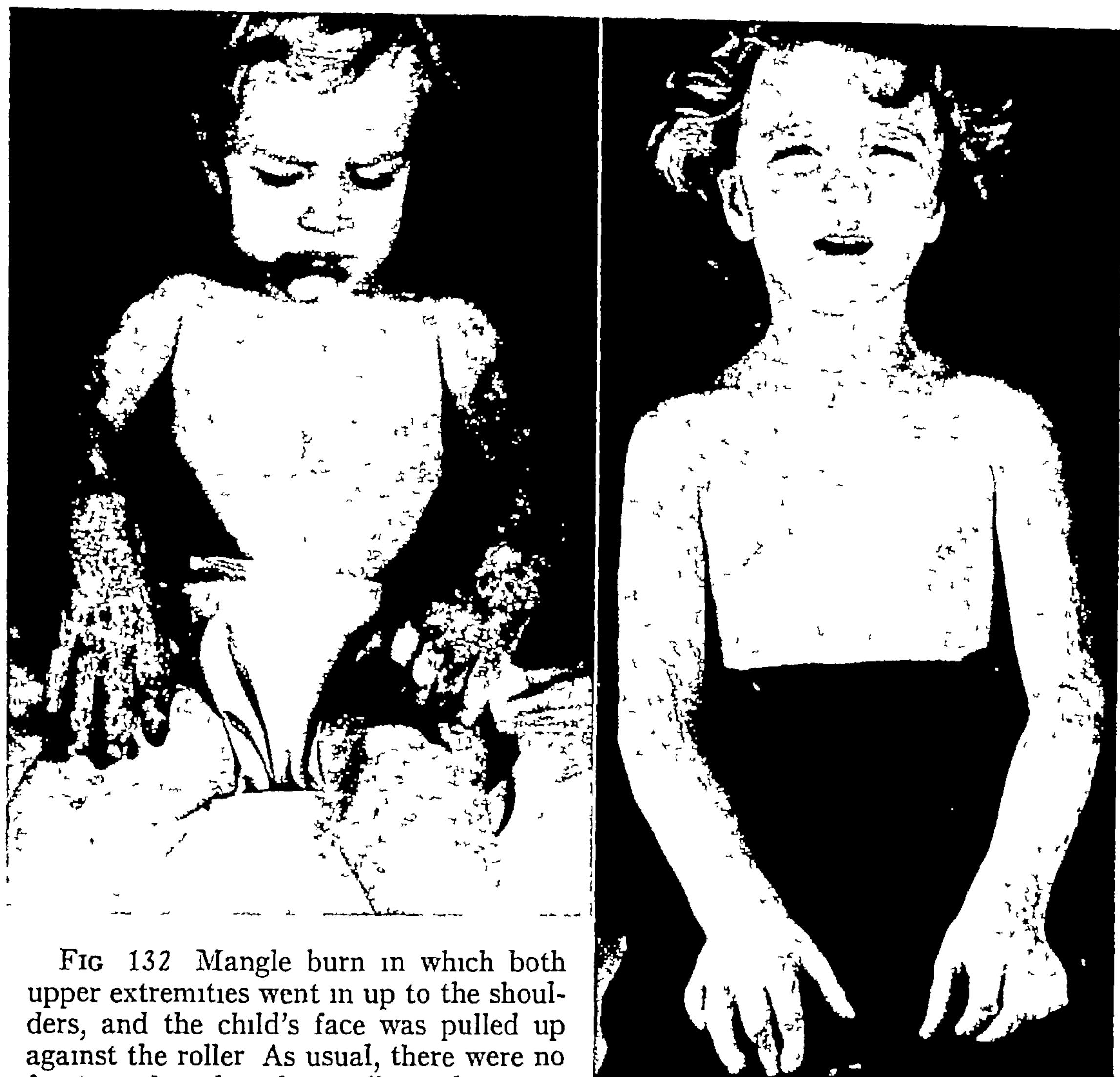


FIG 132 Mangle burn in which both upper extremities went in up to the shoulders, and the child's face was pulled up against the roller As usual, there were no fractures but deep burns Lateral epicondyles of both humeri were burned and separated, as well as central slips of extensor tendons on right middle and index fingers Primary coverage with split grafts Later resurfacing of backs of hands and fingers with full-thickness grafts to get smoother appearance Complete function except in fingers which had burned tendons

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Results are usually good when granulating areas are covered early with large thick split-skin grafts The larger and fewer the grafts, the better the result Some trimming of border scars may be necessary later (Fig 133).

OLD SCAR CONTRACTURES

With the arm itself, the special point of caution is that involvement of the elbow region may result in much the same sort of fixation as is seen in the hand, that is, an actual involvement of the joint and resultant ankylosis (Fig 323) In this condition, the joint may prevent complete opening of the contracture to allow replacement of the necessary skin, and there are then the two factors of contracted skin surface and ankylosis to cause secondary contractures of muscles and tendons There is scarcely a more hopeless situation than this in the entire problem of restoration of these patients Arthroplas-





Fig 133 Split grafting of raw burns. (*Top*) Condition when first seen several weeks after fire burns. Treated by débridement, pressure dressings and two split-grafting operations (*Bottom*) Appearance after 1 year Patient later became a star basketball center

tics at early ages are apparently not very successful but some gains in functional position may be made with wedging plasters and very occasionally, with osteotomies. Direct flap coverage from the chest wall, may be necessary on some of these elbows, following open operation (Fig 134)

However many of the scar contractures

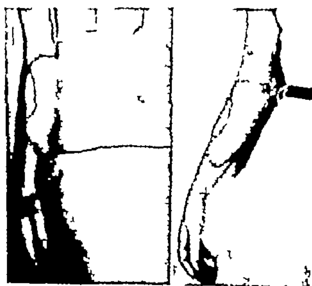


Fig. 134 Direct flap coverage Deep traumatic wound of forearm and antecubital fossa, necessitating putting in flap with arm straight to prevent flexion contracture Flap on and detached in 18 days. Two operations.

of arms and forearms do not have joint involvement, and in these, decortication of all the scar and resurfacing with large split-skin grafts will give good results (Figs 25 and 323) Around the wrist, it is important to avoid exposure of large areas of tendon, as noted in Chapter 15, "Repairs of Hands"

GRAFTS VS FLAPS

Here, as elsewhere, free skin grafts are more generally useful than flaps and are always employed when only resurfacing is needed

However, flaps may be indicated to fill in huge losses for contour (Fig 134), or to provide satisfactory coverage for future bone grafting, tendon grafting, or other deep work Flat, direct, broad-faced, short-pedicle flaps are nearly always best, securing them from the lateral chest wall for the arm, and from the upper abdominal wall and the lower anterior chest wall for the forearm.

Amputation can often be avoided in serious injuries by flap coverage, and subsequent bone and tendon grafting, provided that there is a good blood supply and some nerve supply to the hand (Fig 256)

OTHER INJURIES

The repair of some other injuries to the arm and the forearm are covered in Chapter 30, "Restoration of Defects from Farm, Traffic and Industrial Injuries," Chapter 31, "Repair of Electrical and Cathode Ray Burns," Chapter 32, "Surgical Repair of Radiation Injuries and Atomic Burns," and Chapter 33, "Skin Grafting in Military Plastic Surgery"

18

Repairs of the Body

FRESH THERMAL BURNS

Deep burns are responsible for most of the skin losses in this area and if large may present early danger from shock, and a considerable late mortality rate from extreme debilitation Circular burns of the body are responsible for most of the burn deaths.

If the patient can be brought through the early stages of shock etc., early coverage of some sort will do most to save his life The problem of delineating deep burns from superficial burns always comes up with the same criteria being used as elsewhere except on the thick skin of the back especially in adults At times this will be dead white due to coagulation for several millimeters but the skin may be ¼ inch or more thick and some deeper layers may be alive Instances have been seen of granulating wounds on the backs of adults that appeared ready for grafting, but on close inspection a few fine hairs were seen coming out of the granulations within a few days the hairs were longer an epithelial island appeared around each one and within 2 weeks the back would be healed spontaneously However this is not routinely so and many deep burns do occur on adult backs which require skin grafting Undue delay is not indicated in every case but consideration of this possibility is indicated

In general sloughs over large areas of the body are treated conservatively by cleansing under anesthesia and application of fine mesh grease gauze occlusive dressings every 3 or 4 days for about 2 weeks Some degree of pressure can be used on some of these wounds but dressings around the body should not be constricting enough to interfere with respiration and there must be room for changes in the size of the abdomen with varying digestive states. These patients must also be turned regularly and precautions observed to prevent the development of decubitus ulcers in addition to their burns

In about 10 days to 2 weeks the slough will begin to loosen so that it can be nicked and scissors inserted underneath to dissect it loose by spreading and closing Most of the dissection is done by spreading and the attempt is made to get it off piecemeal if necessary without too much blood loss When most of the slough is off any remaining tenacious remnants can be sliced off with a graft knife, and the assistants can follow along to staunch blood loss by pressure with sponges

The situation is much better if these patients can be made ready for grafting within 14 to 18 days after injury as they will continue to deteriorate until they are grafted They are the ones who need most careful follow-up and treatment of any alterations in blood elements etc.

Large wet body dressings are usually not tolerated very well but sometimes they can be used for a day or two before grafting if thought advisable

At the time of grafting the question



FIG 135 Widespread burn of back and arm repaired with thick split grafts (Brown, J B Closure of surface defects with free skin grafts, Surg , Gynec & Obst 84 862)

comes up as to whether autografts alone, a combination of autografts and homografts, or homografts alone should be used If the burns are largely limited to the body, if good thigh donor areas are available, if the patient's general condition is not too bad, and if half or more of the raw area can be covered with autografts at one sitting, then autografts alone are used (Figs 135, 136, and 133) Blood transfusion probably will be required at the operation and for a few days afterward, but as soon as the patient has recovered from the denudation of his donor sites, and the grafts have sealed a considerable portion of his burn, improvement is usually rapid and dramatic

If the burn is larger, if the donor sites are less, or if his condition is poorer, it may be wise to use a combination of autografts and homografts In such instances, it is preferable to use long sheets of both, alternating them This may result in later creeping replacement of the homografts from the autografts, to give fairly good healing throughout In some instances, the quality of healing may be good enough to be permanent, at other times, later replacement of the scarred homograft areas may be necessary However, the immediate problem in these patients is to get them sealed and healed—with autografts, homografts, scar, or anything that will contain their life fluids and hold them in

In extremely large burns with marked debilitation, the condition of the patient may be too poor to allow denudation of any donor areas, or only small scrappy donor areas may be available Here, it may be best to cover the burns entirely with large homografts (Plate 2) This sealing of the sieve gives the patient's own body chemistry regulatory mechanisms a chance to take over, and with the surgeon's help in replacement therapy, his general condition may improve greatly within 2 or 3 weeks At this time, piecemeal replacement of homografts with autografts can be started and carried out in stages, with the intermittent further use of homografts as indicated, until complete There will be some late deaths in this group

The whole subject of homografting is described further in Chapter 28

Smaller burns of the body do not present the above problems and are débrided and grafted as elsewhere

Burns of the buttocks and the perineum present difficult dressing problems, but they are also not satisfactory for the "exposure technic" as maceration prevents the formation or intact persistence of any protective membrane In general, dressings can be wrapped around the upper part of the buttocks For the lower part, it may be best to have the patient lie on a large gauze pad covered with large sheets of fine-mesh grease gauze This is replaced as often as necessary, with soap and water cleansing and cold creaming of the local parts after each bowel movement

Axillary and breast burns are covered in Chapter 16

Burns of the genitalia are described in Chapter 19

SCAR CONTRACTURES AND GENERALIZED SKIN SHORTENING

Healing of these areas by scar may be a slow and uncertain process, but may occur



Fig 136 Split-grafting raw burns. Coverage in two split grafting operations One later operation for insertion of more skin in the neck and the left axilla





with marked tightness and 'generalized skin shortening" The dispersal of a few pinch grafts or stamp grafts within the scar does not alter the situation much In some cases, the body may be pulled to one side or the other or one extremity may be pulled in others nothing may be visible except the rigid, glazy encasement of scar, or the umbilicus or the nipples may be displaced Movements of the body from side to side or forward and backward, may be markedly impaired or the patient may walk sideways or be totally unable to sit down The difficulty is that there is not enough skin for him to move around in Replacement of all of the scar with sheets of skin graft is the best treatment for these when possible (Fig 137) If this cannot be done sometimes great relief can be obtained simply



FIG 137 Old unhealed burn of chest, abdomen and thigh, with flexion contracture of hip Repaired in one operation by excision of scar and ulcers, opening contracture and covering entire area with thick split-skin grafts

by opening the tight areas, allowing the edges to retract, and grafting the defects (Fig 109)

Flaps are more often taken from the body than applied to it or shifted thereon. However, such shifting of flaps is sometimes done for decubitus ulcers, and for radiation burns (cf Chaps 5 and 32)

RADICAL BREAST EXCISION DEFECTS

These present no particular problems, except that it may be advisable to tack down the flap edges to the chest wall with fine silk sutures before applying a split graft to the remaining defect Drains can be placed under the flaps, with their exits dependent

and at some distance from the graft, to help keep any serum under the flaps from leaking under the graft

Free skin grafts are not apt to grow on bare bone or bare cartilage and if such is exposed, an effort should be made to shift the flaps in some way over these areas.

The graft should be applied in a single large sheet, and it can be sutured in place. A local dressing of fine mesh grease gauze and surgical waste should be used, with strips of Elastoplast for fixation, going about two thirds around the body The usual larger spica dressing may be applied over this



Fig 138 Decubitus ulcer over dead ischial tuberosity treated by excision of dead bone shifting up permanent bipedicle flap and covering donor area with split graft.

INGUINAL DEFECTS

Burns are treated as elsewhere, using a spica type dressing and being careful of the major vessels.

Many inguinal and groin sloughs are the result of inguinal dissections. These are cleaned up and covered with split grafts. The worst ones are seen from the old vertical incisions and this can be minimized by the use of oblique incisions (similar to those for inguinal hernia repair) with a downward prolongation from the medial end and trimming off any ischemic edges just before closure

DECUBITUS ULCERS

Decubitus ulcers are so deplorable that every effort should be made to prevent them They are prone to occur chiefly in the following groups of patients (1) unconscious persons (2) emaciated, disabled elderly patients (e.g in hip fractures) and (3) in paraplegics In the first group prevention consists of turning the patient from back to side to opposite side about every 3 or 4 hours massaging and inspecting the skin each time having the nurses chart their appraisal of the skin condition and calling attention to any areas of persistent redness blanching or blistering In addition to this a responsible ward officer should inspect the skin daily If any such areas are found it is essential to keep the patient off of them until they have recovered and *before* necrosis occurs.

In the second and the third groups of patients it is almost essential to keep the patients on a special turning bed such as the Stryker or Foster frame, with turning every 3 or 4 hours day and night, and special skin care as outlined Paraplegics are most susceptible to decubiti during the first weeks of the disease and good care is especially important during this time In spite of the work concerned decubitus ulcers are so much more easily prevented than cured that rigid attention to these details is well worthwhile

If patients are brought in with small shallow ulcers, the latter will heal under good cleansing care with fine mesh grease gauze dressings if the patient is kept off of them There are no special chemicals or magic formulae for decubitus ulcers the treatment is the same as for other ulcers with the additional measure of keeping pressure off of them

Slightly larger or deeper ulcers can be treated by simple elliptical excision under

mining the edges, and suturing Dead areas of fascia, tendon, or bone must be removed from any decubitus ulcer before it will heal

Larger decubitus ulcers over bony prominences present severe and difficult problems In general, the plan of repair is to delay an adjacent flap first, then later to excise the bony prominence, rotate the flap into place, and split skin graft the flap donor area The flap should be a local one, with a permanent pedicle to bring in its own blood supply, and should be as thick as possible However, it must be obtained without denuding padding from over another bony prominence (Fig 138)

Common bony prominences which are the site of decubitus ulcers and may require excision include (1) the ischial tuberosities, (2) the spines and the posterior plate of the sacrum, (3) posterior iliac spines, (4) anterior superior iliac spines, (5) calcaneal tuberosities, tibial tuberosities and (6) the back of the skull In the last, it is often only the external plate that is dead, in which case it may be excised and covered by rotating in a scalp flap

Tremendous decubitus ulcers can present insurmountable problems and even can cause the death of the patient

In caring for paraplegics, it must be impressed on the patient and everyone around him that braces, physiotherapy procedures or no other one single thing is more important than keeping his skin intact

19

Repairs of the Genitalia

Patients have been cared for with skin losses and deep losses over the genitalia from granuloma inguinale, gunshot wounds, sloughs following injections or topical anesthetics or acids radiation burns war injuries etc Perhaps the largest group have been farm and industrial injuries of the 'power take-off variety in which an overall or pant leg is caught in a turning power shaft and the patient is wound up in it finally resulting in a complete avulsion of the penoscrotal skin

Some of the various lesions will be considered separately

PENILE SKIN LOSSES

Some losses will be seen from burns or chemical sloughs and they are débrided and covered with split skin grafts in the usual manner (Fig 139) If the wounds are old granulating ones it may be necessary to excise the granulations and the underlying yellow bed down to expansile tissue so that there will be no scar sheath preventing expansion in diameter or length. A catheter is then inserted the penis is stretched over it and a split skin graft is applied

If the patient is first seen late after healing by scar and contracture, it may be necessary to excise this in the same manner and stretch out the penis as much as possible before applying the graft This procedure may have to be staged or repeated 2 or 3 times to get the best final result.

If a small flap is necessary for some part a scrotal skin graft will come nearest to providing the necessary thinness softness flexibility and elasticity Abdominal or thigh flaps do not make good penile reconstructions and are rarely, if ever indicated

The technic of split grafting the penis is described in the next section.

PENOSCROTAL SKIN LOSSES

As noted, these losses are usually avulsions from a "power take-off injury' The patient may be pulled out of the seat of a tractor, or it may happen while climbing into it The trouser leg is caught and twisted up the leg to the genital region where it engages the skin of the scrotum and the penis and completely avulses it The skin



Fig. 139 Result of circumferential split graft coverage of penis. Loss was from mistaken injection of topical anesthetic.



FIG 140 Complete avulsion of skin of the penis and the scrotum from "power take-off" injury Inset shows specimen, which was brought in separately, with catheter threaded through it, but traumatized too severely to be used as a graft



FIG 141 Operative repair of patient in Figure 140 The perineum was closed, the testes were implanted in adjacent "slash" pockets in the thighs and the penis was covered with split-skin graft, all in one operation.



FIG 142 Final result of single operation on patient shown in Figures 140 and 141 Normal function No further surgical work or revision was needed

tears loose at the corona, so that the glans is usually left intact The tearing may rip backward into the rectum and there may be further avulsion up over the abdomen, the flank and the back (Figs 140-144)

There is not as much pain as would be expected at the start but it may be severe later Unconsciousness or severe shock has not been noted, but this would depend on how soon help was at hand The skin speci men, in one piece, is usually recovered and brought in with the patient, though it may be badly contused and dirty (Fig 140)

This type of injury does not seem to dam age the deep erectile tissue or the spermatic cord The skin is so loose that it is pulled off of the body to break away at the glans. The separation is probably along the dartos fascia, with the testes held back separately (Fig 140)

Prompt evacuation and operation is obvi ously indicated, and transport for definitive care is most advisable. If delay in final hos pitalization is unavoidable, the testes can be



Fig 143 Penoscrotal avulsion from power take-off" injury (*Left*) Following complete penoscrotal avulsion torn open perineum, and tearing loose of large abdominal flap around the flank to the spine a local physician saved the penis and the testes, and the patient by successful operation He implanted the raw penis under the lower abdominal skin closed the perineum implanted the testes under adjacent thigh flaps, and sutured the abdominal flap back in place with appearance shown at left (*Right*) Shows the raw penis after removal from abdominal pocket several days later and just before the split skin graft was applied



FIG 144 Final result on patient shown in Figure 143 There was normal function, and the patient was not desirous of any attempt at making a scrotum (as none of these patients has been) Married 8 years later, and in the following year a normal baby girl was born Normal spermatogenesis

saved by implantation just under the adjacent skin of the thighs, and the penis can be dressed, or implanted temporarily under a slash pocket in adjacent skin, such as the abdomen (Fig 143) For these dramatic injuries, consultation may be held by telephone, and the local surgeon can carry out implantation of the testes, instead of just dressing them open with the added possibility of twist or thrombosis of the spermatic vessels

In most of these patients, the operative work will consist of (1) closing the perineal defect, (2) implantation of the testes, and (3) skin grafting the penis—all of which are carried out at the same time, if possible

For testes implantation, a short incision is made on each thigh, just below where the testis will reach easily, from this incision, the skin is undermined thinly upward, making a tunnel through to the region of the external ring Each testis is then gently pulled down through the tunnel to the superficial pocket just under the skin at a level of a normal scrotum, with great care to maintain the cord without blockage or twisting, and the skin incision is closed A bulge is produced by the testes and it is covered about three fourths of the way around by skin alone There is evidence that the temperature in this locale is lower than general body temperature, such patients have retained their reproductive function as much as 8 years later[1]

Grafting the Completely Denuded Penis Catheterization is necessary (which probably already has been carried out). The penis is elongated to its full extent on the catheter and covered with a single large split-skin graft, suturing it to the dorsum and along the corona and the base if necessary The graft is taken from the thigh or some suitable nonhairy area and is about two-thirds thickness As a dressing, fine-mesh grease gauze is wrapped around the penis, then covered with a thin layer of surgical waste or gauze, and local pressure is made by wrapping a 1- or 2-inch strip of Elastoplast spirally around the penis from the base outward A large hip spica dressing may be added for further immobilization and protection After-care of the graft is about the same as in other areas If there is need for further graft, or additional loosening, more skin can be added later Split-skin grafts undoubtedly provide the best covering here, with better elasticity flexibility, looseness and sensation that could be provided by any flap

Total reconstructions, using a tubed flap and a bone or cartilage implant, have been described in the Russian literature and elsewhere Such an inert, insensitive organ would seem to be so lacking in function that it would amount to little more than a prosthesis.

ELEPHANTIASIS

Chronic elephantiasis of the male genitalia of unknown origin is seen occasionally.

[1] Brown, J B, and Fryer, M P Peno-Scrotal Skin Losses, Ann Surg 145 656, 1957



FIG 145 Large elephantiasis of penis and scrotum of many years duration with resection and immediate coverage with split-skin grafts in one operation

The swollen tissue is ordinarily outside of the cavernous bodies and the urethra and outside of the dartos tunic

The best treatment presently known for some of these cases is excision and coverage with split-skin grafts (Fig 145) A spiral Elastoplast dressing is used for the penis and a tie-over dressing for the scrotum.

RADIATION BURNS

Severe radiation dermatitis of the female genitalia sometimes occurs as the result of treatment for pruritus vulvae or pruritus ani or the combination (Fig 146)

Repair of this has been described by others with flaps but in general it is probably best to do it with split skin grafts in most patients

If there is considerable leukorrhea or trichomonad or monilia infection this should be brought under control before operation and some treatment during the post operative period may be necessary

Before operation the colon is cleared out by laxatives and colonic irrigations. After operation the patient is kept on a low residue diet and opium pills or other constipating drugs for about 10 days until the



FIG 146 Radiation burn of vulva perineum buttocks and perianal area up to pectinate line as result of treatment for pruritus The patient was unable to sit down for 8 years. Covered with split skin grafts in two operations one side at a time (*Right*) Appearance 5 years later with no further trouble

grafts are well seated and then the colon is cleared out again

A urethral catheter is left in place for about 10 days postoperatively, to avoid urinary soilage during this period

As elsewhere, results are better if operation is undertaken before extensive ulceration or the development of carcinoma has taken place.

The operation usually should be done in the stirrups position If the area of involvement is very extensive, it may be best to do one lateral half at the first operation, and the other half at a second operation 2 or 3 months later, otherwise, the entire resurfacing may be done in one operation

As elsewhere, the area of skin involvement severe enough to require resurfacing is marked out with methylene blue, this frequently will involve both labia majora and the surrounding skin, and the perirectal skin inward to the pectinate line The excision is done deep enough to get good capillary oozing throughout the field, and all spurting vessels are ligated with 000 white silk The split-skin grafts are cut about two thirds thickness and as large as possible, preferably not using more than one for each side The sutures around the outside of the grafts can be left long, as can the ones around the pectinate line of the anus and around the inside of the vulva, and these can be tied together across the surgical waste dressing to secure it and make local pressure An indwelling catheter and a rectal tube are left in place, the legs are let down flat on a table, and then a large double hip-spica dressing can be wrapped on for additional pressure and immobilization

One postoperative problem that can develop is contracture of the circular scar around the anus If this is out a centimeter or so from the pectinate line, probably it will not be troublesome, but if it is in the pectinate line, it can result in an external stricture This can be remedied secondarily by local "Z" plasties, or by one or two cuts across the scar, spreading them, and inserting more graft These procedures are usually not necessary, but the possibility should be noted and follow-up examinations carried out for some months

The operation has given great relief to some patients who had not been able to sit down for years, but could do so comfortably after the skin grafting was done

CONGENITAL ABSENCE OF VAGINA

So much has been written about this relatively rare anomaly that probably everyone knows all about it

The milder cases are commonly treated by repeated local pressure in the area to create a dimple first, and then gradual persistent dilatation Several gynecologists have reported good success in some patients by this method alone When this is not feasible or is tried and fails, then a vaginal vault can be surgically dissected and lined with a split-skin graft

It is usually not best to do the operation until a few months before the patient is to be married, as the surgically constructed vagina probably will require periodic dilatation for full maintenance

The dissection is often done by or with a gynecologist A catheter is inserted into the urethra, and a finger in the rectum, to act as guides to avoid injury to these two important structures Once the dissection is well started and carried past the urethra, most of the posterior area can be opened by spreading and blunt dissection Care is taken in the cul-de-sac area to avoid opening the peritoneum

The skin graft is wrapped around, or sewed around a mold of the desired shape and size This mold is constructed beforehand and may be made of acrylic, lucite, balsa wood, or other materials Commonly, a groove or a trough is made in the upper outer portion, to fit around the urethra and avoid pressure on it One or two metal screw-eyes can be inserted in the outer end and to them are fastened long pieces of

rubber tubing which in turn are a T belt, or saddle belting or suspension to hold the mold firmly up in place It goes without saying that the skin graft is put on the mold with the raw side out the mold is inserted and anchored in place with the belting and then a double hip-spica dressing is wrapped on for further pressure and immobilization The bladder and the bowels are cared for as noted under radiation burn repairs of the genitalia.

The mold is removed the first time in about 1 week, any extra graft is trimmed off, the interior gently cleansed and the mold reinserted This is repeated every 2 or 3 days for the next 2 or 3 weeks Ordinarily, the patient is allowed to be up and walk in about 2 weeks and to leave the hospital a few days later A new and somewhat smaller mold is usually fitted at that time, and she is taught to remove it for cleansing and to replace it daily It should be worn for some months or most of the time until she is married

This skin does not metaplase into mucosa but always remains as skin However it is the best repair available and patients and their spouses have reported it as satisfactory

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Repairs of the Thighs and the Legs

Open wounds and contractures of the thigh and the leg may respond to free skin grafting as well as other areas (Figs 1, 2, 24, 26, 32, 33, 147-151), but some qualifications about repairs in this area should be mentioned

FRESH THERMAL BURNS

The problem, as always, is to get the slough off as soon as possible in deep burns and to cover them with split-skin grafts Small burns can be done very early, as out-



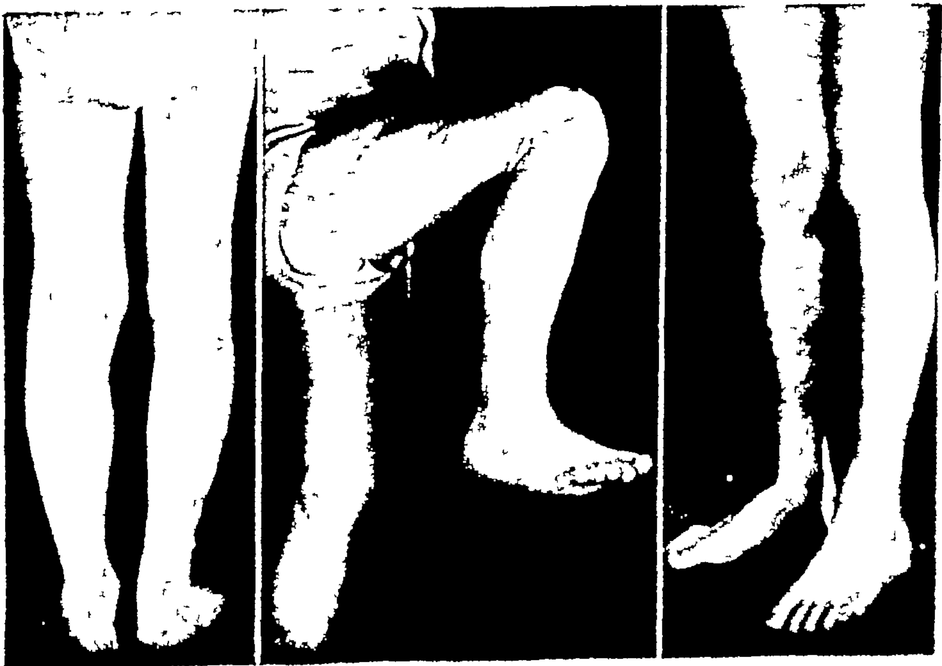


Fig 147 Complete circular loss repaired in 3 split-graft operations Shown after 2 years (*Bottom, right*) Same type of burn 8 years after one single operation (Surg. Gynec & Obst 72 848)

lined in Chapter 5 Larger burns are accompanied by more shock and systemic disturbance so that more care is necessary Frequently however the patient will be in satisfactory condition within 5 to 7 days so that the slough can be removed from one extremity under a tourniquet and from the other one a day or two later If the slough is still tenacious at this time and its removal is too tedious and opens up too many vessels, it may be best to wait a few more days until it comes loose easily with scissors dissection underneath In any event the slough will usually demarcate and can be removed earlier if the wounds are treated with occlusive pressure dressings rather than "exposure"

After the slough is off the patient is kept on local saline dressings and systemic antibiotics for a few days then the raw areas are covered with large split skin grafts The work will be expedited considerably if the largest possible grafts are obtained—often from the back (Fig 50) Little narrow ribbons 1 or 2 inches wide are not very useful and usually good grafts about 4 inches wide and 2 to 3 feet in length can be obtained from a good donor area on an adult by free hand cutting with a knife (Fig 147) Most dermatome grafts are too small for large areas.

The grafts can be applied lengthwise or occasionally can be spiraled around the leg from below upward. In any event suturing is often not necessary and the grafts can be quickly "snubbed on"—that is wrapped on with a roll of fine mesh grease gauze bandage Surgical waste is applied outside this then long gauze pads are wrapped on with gauze rolls with final pressure being applied by a tight external bandage fixed with plenty of adhesive tape spirally wound up and down In large wounds it is often necessary to immobilize the knee and the ankle and this can be done with a posterior plaster splint wrapped firmly on the outside Wounds near the groin may require a spica type of dressing

In general if any of the lower extremity is grafted it is well to include all distal parts to the toes in the pressure bandage—otherwise there may be swelling of any exposed distal parts.

Foot drop occurs rarely in children but is always a hazard in adults so that arrangements must be made to keep the feet up in proper position until the patient starts walking

The first dressing of grafts is done in 4 or 5 days and any overlapped areas of graft are trimmed off any pustules or hematomas are opened any dead graft removed gentle washing with saline is carried out and the pressure dressing is reapplied This routine is repeated every 1 to 3 days until the grafts are solid and the extremity is healed Then they are cared for as outlined below

SPECIAL POSTOPERATIVE CARE FOR ALL LEG AND FOOT GRAFTS

Free grafts on the leg and the foot require careful postoperative treatment because of weight bearing dependency and the long column of hydrostatic venous pressure involved many such patients will have varying degrees of varicose veins and valvular incompetency

The patient is not allowed to let his leg hang down until 2 weeks or more have elapsed after successful grafting and then for a period of only a few minutes increasing the length of time gradually Constant pressure is kept on the grafts using an elastic bandage with cold cream and a few thin layers of gauze beneath, until the grafts are tough enough to use an elastic stocking A few days later walking and weight bearing are started using crutches at first if necessary The elastic bandage or stocking is kept on until the patient can get around without cyanosis or edema of the grafted areas This may be from a few days in most children to a few weeks in most adults but may continue forever in some elderly adults with very poor circulation



FIG 148 Large chronic leg ulcers open continuously since patient was burned four years ago Repaired in one operation by transferring the skin of the entire back (in large split grafts) to the lower extremities after excising the ulcers and surrounding scar

Successful grafts have been lost when the above precautions have not been observed Premature dependency or weight-bearing may produce sudden widespread epithelial loss by blistering or deeper loss from cyanosis, venous stasis, etc

CHRONIC OPEN BURNS

Large complete circular losses may never heal, such wounds have been seen that have been open continuously for 53 years. There is slow, if any, epithelization from the distal margin, and if the distance is too great, epithelium from the upper margin may never struggle across These open wounds may cause great debilitation because of constant leakage and because the patient is necessarily confined or immobilized by them



FIG 149 (*Top*) Unhealed burn 3½ years old The patient was in bed the entire time (*Right*) Complete healing in one thick split-graft operation. Deep scar decorticated in layers down to good bleeding base, but some coverage left over both malleoli. (Clinics 1.25)

There may be cachexia, demineralization of the bones and spontaneous fractures, decubitus ulcers, recurrent bouts of pneumonia etc. Granulations at the base of the wound may contract down into hard scar, and in circular wounds, impede circulation and produce edema of distal parts Impossible and grotesque contractures may occur Large wounds may be fatal, if left unhealed It is with this realization that such legs have often been amputated in many parts of the world, but repair is usually possible and preferable if there is adequate circulation and nerve supply to the feet (Figs 29, 148 149)

If the patient is greatly debilitated when first seen, he may require building up for a period with repeated transfusions, forced tube feedings, etc., before any surgery except local cleansing can be done.

If the legs are covered with grease, scabs and detritus, daily soaking and cleansing in a bathtub full of warm saline may be very helpful as a preliminary measure The difference that a few days or a week of this may make is often amazing, and patients can often "kick out any secondary contractures in the tub (Fig 34)

At least one final cleansing and débridement is done in the operating room under general anesthesia before the grafting operation

At the time of the grafting the granulations are always sliced off these old chronic wounds down to a firm yellow base If this base is tight, it is opened through several longitudinal incisions to allow the leg to expand in circumference If there are contractures, further scar excision may be necessary at this time or later After the wounds are thus prepared, and good hemostasis secured (by tying off spurting vessels with 000 white silk and using pressure on others) the grafts are applied

Contractures may necessitate further secondary work later

OLD SCAR CONTRACTURES

Some of the most extensive burn contractures occur in the lower extremities and huge amounts of skin graft may be necessary for their repair (Figs 150 151, 152) Flaps are seldom indicated and would rarely be adequate

It may be accepted as an axiom here that opening across the middle of a large expanse

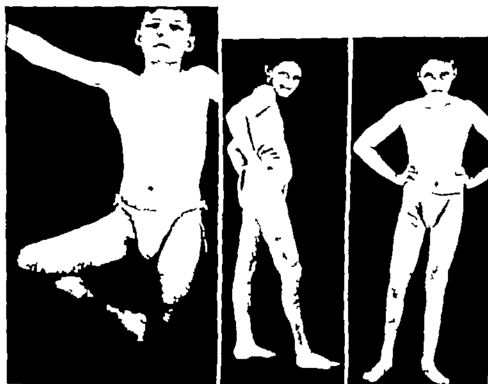


FIG 150 (*Left*) Unhealed extreme deformity after 18 months Patient came in for amputation. (*Center and right*) Result of 3 split graft operations. Function has persisted through a growing period of 5 years. (Clinics 1 25)

of scar, spreading it apart and inserting a skin graft will produce little or no improvement Large areas of scar must be excised—all of it, whenever possible—and large resurfacing done In these legs, the scar contracts vertically, horizontally, circumferentially, and in every direction—and only total removal will restore the pre-existing condition At times, several operations will be necessary to complete this, especially if both extremities are involved

After scar excisions, if the margins of the defect are long vertical lines, it should be remembered that they will contract in length during the healing of the graft, therefore several crosscuts, or "darts," should be made in them and spread open into triangles, before the grafts are applied This is especially true about the hip and the popliteal areas

Here, as elsewhere, the largest possible grafts will effect the best repairs

Occasionally, in opening severe knee contractures, the major vessels and nerves may be shortened and "bowstrung" across the defect This is always a difficult situation First, it is well to be certain that the skin is loose on the medial and the lateral aspects of the knee, and that nothing else is preventing straightening. Secondly, and after this, it may be worthwhile to make a careful dissection proximally and distally to loosen and mobilize them, and try to get enough length If everything else fails, then it may be advisable to apply wet dressings around the knee defect, and put skeletal traction on the lower leg for a few days to try to stretch them before grafting If done, great caution is necessary to see that the circulation and the sensation of the foot remain satisfactory After a few days, grafting is done, and traction may be continued for 1 or 2 weeks, and then plaster fixation for an additional 2 or 3 weeks Even with all of this, a repetition of the procedure may be necessary after a few months, in some instances



FIG. 152 (*Top*) A patient sent in for amputation one year after burn (*Bottom*) Restoration after 6 months with split grafts. The leg was opened at first operation to within 15° of complete extension The remainder was accomplished by direct skeletal traction by Dr C. H Crego The defect was then covered with split grafts in two operations. There was no foot drop and the patient reported playing basketball 8 years later (Surg., Gynec. & Obst 60 379)

If a patient presents with extensive open areas and some contracture, it may be best to graft the open areas first and heal the extremity and then open the contracture later

In all contractures it is well to remember that there may be primary or secondary or both components

Primary contracture is from granulation tissue aging and contracting down into scar this is organic, mechanical and fixed It is not affected by any medicine or radiation or anything else except excision and replacement with normal tissue Attempts at stretching or traction may break the scar producing hemorrhage, which is in turn replaced by more granulation tissue more scar and more contracture

Secondary contractures are not true contractures but are deformities due to

muscle spasm They are not fixed and may even be partially voluntary (to relieve discomfort), in some instances. These are the leg contractures that may be "kicked out" in warm baths or may yield to hot packs massage manipulation, gentle traction, etc If there is an question in any particular contracture as to the part played by these two components, it may be settled readily by gentle stretching under general anesthesia

BURNED TENDONS AND BONES

In any wound, burn or avulsion or otherwise, if bare tendon or bone is exposed to the outside for a week and shows no sign of covering with granulations, it usually means that it is dead and will have to come out There are some exceptions to this, but fewer than most surgeons think

It is not always necessary to remove these before grafting or to await their separation, the remainder of the defect can be grafted right up to these structures, and they can be removed secondarily The circumstances in each instance will dictate whether primary or secondary removal is best (Figs 32, 33).

If it is thought that only the outer plate of a bone is dead, it is often best to wait until spontaneous separation begins and then pry it off. In other circumstances, however, one should go ahead and chisel off, or rongeur off, small amounts, layer by layer, until bleeding bone is reached everywhere Then one can await a granulating bed, or resurface it immediately if it seems to be advisable

If a dead tendon is exposed all around, and it is isolated, it might as well be removed However, if only the dead surface of a tendon is exposed, and it is the most superficial of a group of tendons, removal of it may be followed by drying out and death of deeper tendons For this reason, it may be worthwhile in some instances to await the growth of a fine layer of granulations between this tendon and the subjacent ones before removing it, unless there is some other compelling reason to go ahead Of course, if immediate flap coverage is available there may be no reason for waiting

Some large tendons and aponeuroses may have some minute blood supply within them which may give rise to granulations This is often true of the Achilles tendon and the quadriceps aponeurosis. If a patient is seen in which these structures have been exposed and dead in appearance for several days, it may be best to wait another week or so, then slice off the surface layers and apply wet dressings for a few days in the hopes that granulations will appear, surprisingly enough, they often do.

In removing scars from over the Achilles tendon, the malleoli, the patella, or similar structures, it is important to leave a little film of soft tissue over them to support a graft Pressure dressings in such areas must be very cautious and gentle

CHRONIC LEG ULCERS

Chronic leg ulcers are perhaps the most neglected of all common wounds (Figs 28 29, 148 149, and 299) All too frequently they are turned over to the least-experienced personnel to try out this or that antiseptic or type of compression dressing without the realization that any healing obtained probably will be only temporary

A leg ulcer that is open intermittently or continuously over a long period finally loses all relationship to its original etiology and becomes an *ulcer per se*. New granulations are formed repeatedly and contract down into successive layers of dense scar until the minute surface blood supply in the area is choked off Such dense scar may even calcify and be mistaken for a sequestrum on roentgen-ray films The border epithelium may pile up into thick keratotic edges when the scar will not nourish it enough to go across the wound, or the scar may furnish almost no wound stimulus so that the epithelial layers may become dormant and heal to each other to form a permanent open edge



Fig 153 Chronic, recurrent ulceration in a thin scar over the tibia, following osteomyelitis many years ago Many of these patients think that they are having recurrences of the osteomyelitis when they are actually having breakdowns of the covering scar Repaired by excision of the scar, by switching a large, thick double-pedicle flap from the side of the leg to the medio-anterior surface of the tibia, and split-grafting the donor area

No amount of treatment of the original etiology will heal such a wound Dupuytren recognized this in the middle of the last century and found that wide surgical excision of the dense scar was sometimes followed by spontaneous healing

When the scar is not too dense or deep so that there is still a little surface blood supply, it may be possible to encourage the border epithelium to creep across the wound and cover it However such coverage often proves to be unstable and breaks open again after even trivial injuries.

As a routine such ulcers are studied to reveal their original cause, and this is treated when possible This may involve ligation injection or excision of varicose veins sympathectomies for vasospastic conditions or antiluetic therapy A special attempt is made to eliminate edema from the leg whether from cardiac, renal or local vascular origin All this usually requires considerable consultation with other services

Following this the patient is put to bed with the leg elevated and with a wet pressure dressing on it Daily mechanical cleansing is done and systemic antibiotics may be employed After the area seems to be as clean as it is possible to make it, the scar is decorticated in layers down to a bleeding base This may be to a deeper level than where a few squirting arterioles are first encountered, on down to where there are multiple close points of capillary bleeding This problem may be most annoying over the internal malleolus but it is usually best to expose little or no periosteum. If very little subcutaneous tissue is left in this area it may be advisable to have the patient wear a small pad over the malleolus permanently to protect it from trauma

After the ulcer has been completely ex

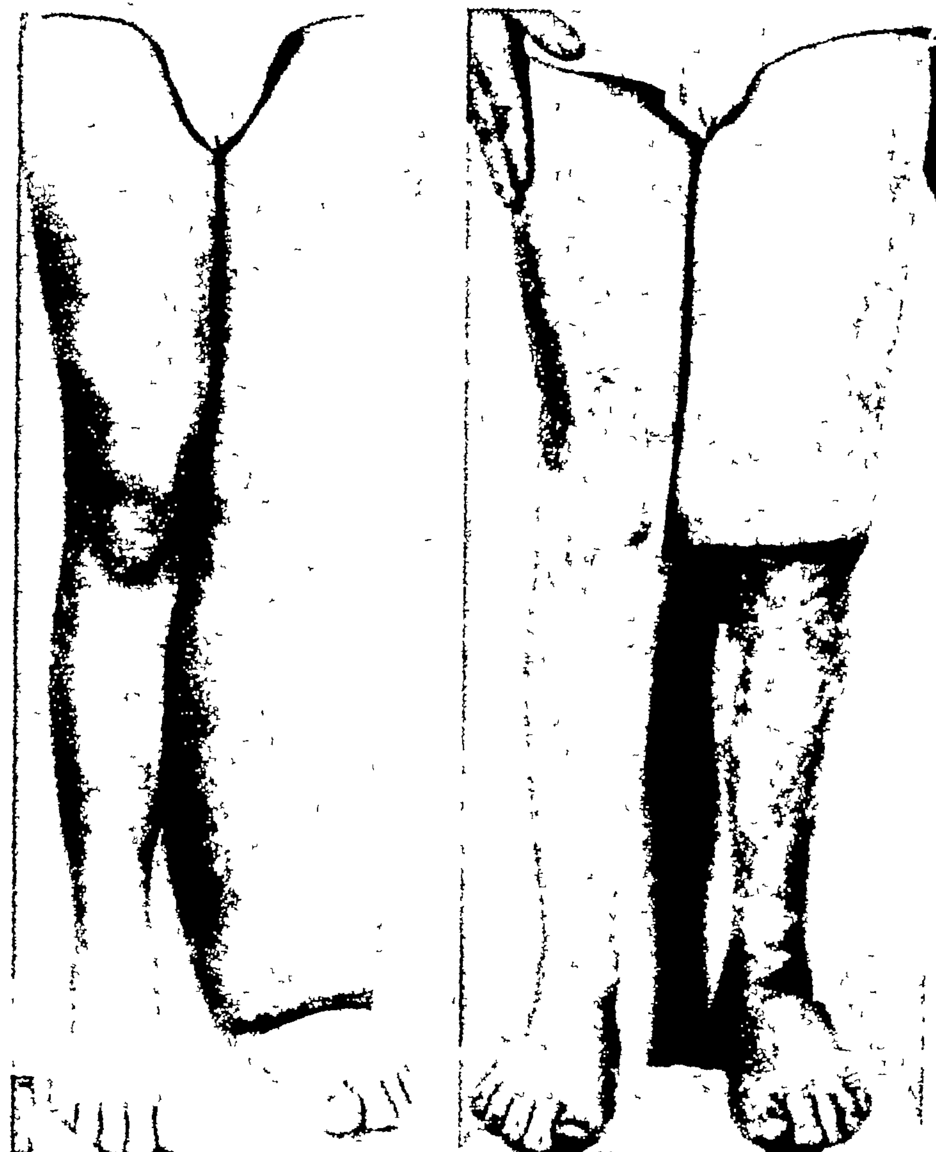


Fig. 154. Huge elephantiasis of leg of many years duration, with frequent weeping and skin breakdowns Excision and coverage with split grafts in one operation. (*Right*) Result 3 months later

cised, hemostasis is secured by pressure with warm saline gauze or weak adrenalin sponges, and a single split graft is applied often by "snubbing" it on without sutures Postoperative dressings are done in the usual way, allowing the leg gradually to become dependent about the 3rd week. A custom-made elastic stocking is worn until at least 3 months after operation and afte that as long as is necessary to control a cyanosis in the graft or edema in the le The co-operation of the patient's persona physician is secured in keeping edema out of the leg and in reporti ly any slight break in the surfa n be treated before it spr h a regimen most intellig eet

good permanent healing by skin grafting and by such treatment of the original etiologic factors as may be possible

Excellent articles on the etiologic factors and mechanisms of these "stasis ulcers" have been written by Carl A. Moyer and Harvey P. , and a n Blocker and S

FROM

fection that may even be mistaken for a recurrence of the osteomyelitis. If bone infection can be ruled out, it may be best to swing a long double pedicled flap from either the medial or the lateral (be careful not to injure the peroneal nerve) edge of the wound over the tibia and simultaneously graft the original flap site (Fig 153)

FLAP REPAIRS

Compound fractures of both bones of the leg with avulsion of the overlying soft tissues always present a serious problem and frequently require good co-operation between the orthopedic and the plastic services. After any local infection is controlled it may be possible to cover the area temporarily with a split graft to get all remaining inflammation to subside. After this flap coverage may be substituted to provide decent tissues to cover any subsequent bone grafts. At times, the flap may be a direct double pedicled or a delayed single-pedicled one from elsewhere on the same leg More often a cross-leg flap will be necessary because of excessive tissue loss or scarring on the same leg Open jump-flaps carried on the forearm are occasionally necessary but caterpillar flaps seem to be too tedious and risky to justify their use (cf Chap 33)

ELEPHANTIASIS

Congenital elephantiasis lymphedema, or "Milroy s disease" is a serious problem for which there is no satisfactory solution at the present time The older Kondoleon and other operations were notoriously unsuccessful The best operation now is to excise the entire area of involved skin and subcutaneous tissue all around the leg (under a tourniquet) make a few openings in the fascia and then cover the fascia and the muscle with large split-skin grafts The sole of the foot and the toes are usually not operated on though the dorsum may be resurfaced it may be wise to leave original coverage over the Achilles tendon Grafts are cut from the removed skin at times, but often



FIG 155 Carcinoma in burn scar (Marjolin s ulcer) Resection and split grafting in one operation.

it is boggy and warty so that better grafts can be obtained elsewhere

The immediate results are dramatic and gratifying and remain so for some years after which there may be slow recrudescence and recurrence of the process Subsequent work may then be necessary The etiology and the pathogenesis of the lesion are not understood.

It is said that this same operation is now being used some in Africa and in other tropical areas for filarial elephantiasis.

Milroy s disease can vary from mild to very severe Some of the latter may have repeated infections chronic ulceration and crippling to the point of amputation unless some such operation as the above is performed (Fig 154)

MARJOLIN'S ULCER OR CARCINOMA

This is a squamous carcinoma arising in old scars, especially burn scars which have been under tension for years. It is particularly common on the back of knees and on thighs, and sometimes it is seen on the scalp There is usually a history of repeated cracking open and healing until it finally remains open, spreads, forms a crater and

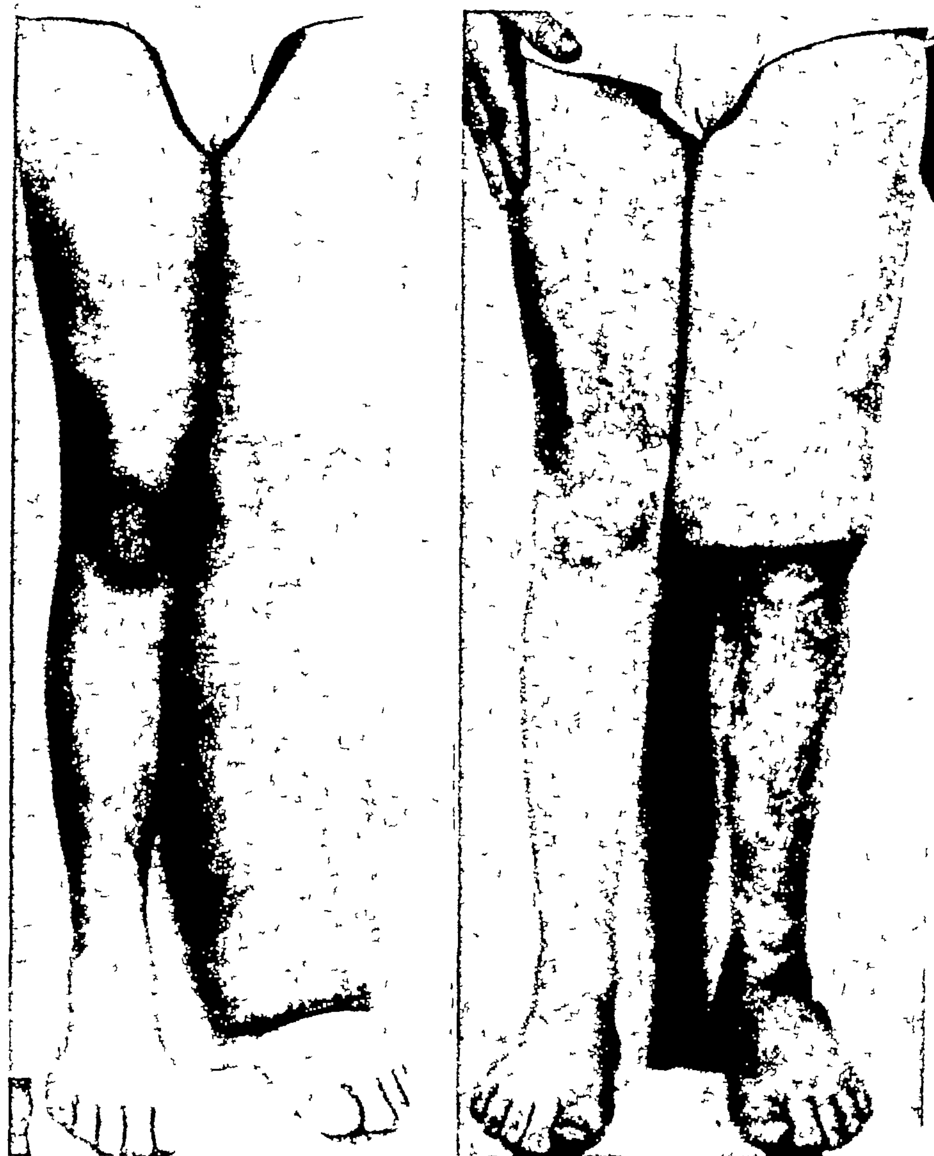


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Excellent articles on the etiologic factors and mechanisms of these "stasis ulcers" have been written by Carl A Moyer and Harvey Butcher, and also by Truman Blocker and Steve Lewis

SURFACE RESIDUALS FROM OSTEOMYELITIS

Widespread osteomyelitis of the tibia may leave a chronic surface-healing problem if extensive saucerization has been necessary In such instances, the resultant thin scar over the bone is easily broken open by slight trauma, with ensuing soft-tissue in-

fection that may even be mistaken for a recurrence of the osteomyelitis If bone infection can be ruled out it may be best to swing a long double-pedicled flap from either the medial or the lateral (be careful not to *injure the peroneal nerve*) *edge of* the wound over the tibia and simultaneously graft the original flap site (Fig 153)

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FIG 156 Black gangrenous radiation slough, following intensive therapy (elsewhere) to leg ulcer which was mistakenly thought to be carcinoma when piled-up epithelial edge biopsied There was a necrotic section of fibula under this, and extensive débridement was done, followed by slow granulations and finally split graft coverage (*bottom*)

becomes indurated It is slow to metastasize and usually can be cured by very wide resection and skin grafting (Fig 155)

RADIATION LESIONS

Radiation lesions on the legs may be seen from the treatment of leg ulcers, giant-cell bone tumors, keratoses, skin carcinomas, fungous infections, superfluous hair, etc (cf Chap 32)

One of the most pathetic situations is that in which an ordinary chronic leg ulcer develops piled-up hyperplastic epithelium around the edges (Fig 156), a biopsy is misdiagnosed as possible carcinoma, and tremendous amounts of radiation are given Since the circulation is poor anyway, the effects may be severe with the sequestration of bone, sloughing of tendons, muscles, etc, and may even end up with amputation

Most legs in older people seem to tolerate radiation very poorly

Treatment, when not too severe, is excision and free skin grafting Localized severe lesions may require a permanent pedicle blood-carrying flap for repair

OTHER LESIONS AND REPAIRS

Other lesions and repairs are described in Chapters 5, 11, 12, 21, 28, 30, 31, 32 and 33

21

Repairs of the Feet

Defects and losses of the skin and subcutaneous tissues of the foot cause major *discomfort and disability*, and trouble continues until there is complete permanent healing Resurfacing the foot with free grafts and flaps may result in adequate results for function and comfort, but the processes may be technically difficult and also troublesome for the patient. Therefore, it is important to realize that there are numerous qualifications and limitations of this resurfacing in trying to secure solid permanent closure of even a small defect

Direct suture of the skin of the foot after a loss, especially in the sole is limited to repair of linear defects and may not be effective over bearing surfaces In the center of the sole, for example, some excellent results can be obtained however, deep sutures of any kind are apt to cause trouble, and deep wire is not used because of possible irritation and wart formation Simple direct suturing and careful strapping and bandaging are essential parts of the operation

Leaving small wounds open to heal in themselves in the sole may be successful in "silent" areas such as the middle of the arch, but in bearing areas the resultant scar may be so painful that a secondary repair is necessary

Small surface wounds or defects on the sole of the foot are capable of producing prolonged and extreme disability and their successful repair may call for more skill and judgment than in most other areas

SPECIAL ANATOMIC CONSIDERATIONS

In its skin and subcutaneous make-up the sole is a congenitally specialized organ or structure The same sort of tissue does not occur elsewhere in the body (except in the palm), and if it is once lost, it cannot be replaced and a substitution becomes necessary Tissues transplanted to the sole from other areas do not undergo metaplasia to become a normal sole, nor will walking on the new tissue cause it to do so, and the substituted area will require care and protection to prevent irritation and ulceration Because of this, transfer of skin from the opposite sole might seem to be indicated, but the transfer would result in added debilitation in most instances. If hair-bearing skin is transplanted to the sole, the hair will continue to grow, except as it is worn off, because the foreign skin does not take on the characteristic of producing the thick keratinized layer that occurs in the normal sole

The surface over the normal heel cord is also specialized and though the skin over the rest of the dorsum is not as specialized the whole foot including the malleoli and the dorsum requires an intact surface for the protection of these areas. In surgical procedures on the foot, care is taken to keep incisions at a minimum, and an attempt is made to assure adequate coverage and prompt healing The dictum that deep healing and proper function are dependent on an intact surface is nowhere more true than in the foot.

The sensory nerve supply of the foot is of great importance, and if anesthesia occurs either in scarred or repaired areas, there is apt to be trouble from trauma and ulceration. If nerves remain present in the general area, sensation will develop in both grafts and flaps to a worthwhile protective degree and the grafts may develop practically nc



FIG 157 Traumatic loss of forefoot with skin lost over rest of foot, coverage with thick split graft Patient runs and pursues all normal activities but has some annoying wart formation on the sole and requires protection

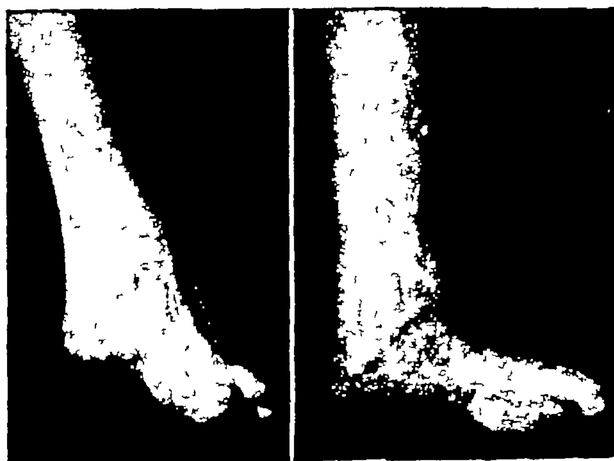


FIG 158 Restoration in one split graft, preceded by bone correction by Dr Crego Function satisfactory with graft on sole of foot after 9 years of growth Free grafts are satisfactory on the foot only if sufficient deep pad has been left, otherwise, a pedicle flap is used (Surg, Gynec & Obst 72 848)

mal sensation But if the nerve supply has been so interrupted that no nerves are available, there is apt to be chronic ulceration to start with, and it may continue in the repaired area The care of the anesthetic foot is tedious but must be vigilant if trouble is to be avoided

FREE SKIN GRAFT REPAIRS IN THE FOOT

Free thick split-skin grafts are used generally for surface repairs, if there is an adequate subcutaneous pad of tissue to carry the graft and form a supporting cushion Stable covering for the entire sole may be obtained from a free graft in such instances (Figs 157-164) If this pad is present, the repair is better with a free graft surface



FIG 159 (*Left*) Painful deformity from burn (*Right*) Complete restoration of function from one split-graft operation, persisting after 9 years (Clinics 1 25)





than any flap transferred from a distance By this plan much time can be saved and morbidity reduced Most thermal burns of the feet can be treated in this manner

Free grafts also may be used as a trial measure or to secure temporary healing in radiation lesions avulsions cancer and other lesions and a flap may be put in secondarily

Fig 160 Molten lead burn of foot. Excised and split grafted a few days later with result shown at right. Satisfactory function for many years now, with patient working daily at same job in smelter

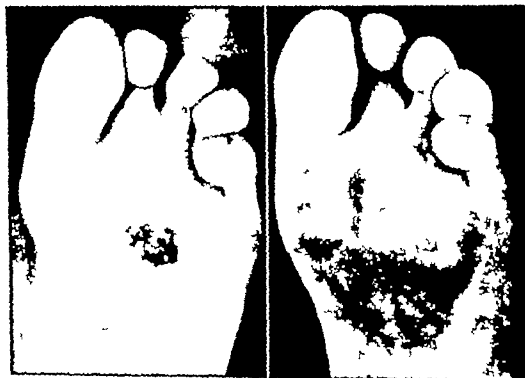


Fig 161 Radiation burn and carcinoma of the foot (*left*) following treatment for plantar wart Wide and deep excision was done but enough soft tissue padding remained so that a split graft gave a good final functional result (*right*)

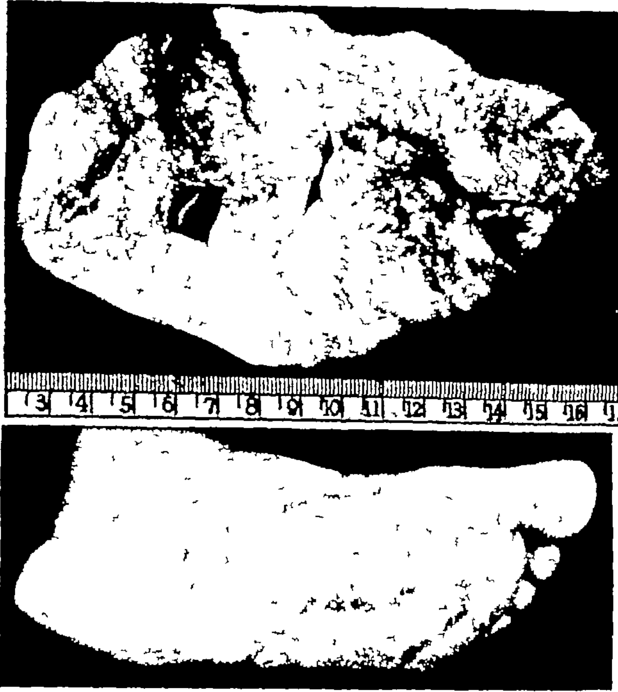


FIG 162 Split-skin graft to sole of foot (*Top*) Excised specimen of radiated skin and wart formation close to carcinoma (*Bottom*) Result following split-graft coverage in same operation Function is satisfactory for golf and normal activities



FIG 163 Split grafts to soles (*Top*) Radiation burns of both feet. (*Center and bottom*) Early result following excision and split-graft coverage in same operation Final function quite satisfactory.

if it becomes necessary The occasional extra operation is well worthwhile in the consideration of trying to avoid a cumbersome cross-leg flap and also in having a clean healed recipient site if one is necessary

The "skin graft dressing" method for raw feet may save many extremities, and amputation can be left to secondary consideration if nerve and blood vessel supply is reasonably intact One dramatic case of this kind was in a young boy who lost the entire skin and the anterior third of his foot in a railroad accident and was brought in for midleg amputation Immediate dressing of the raw area in thick split-skin grafts saved the foot and produced stable permanent healing in one operation His subsequent care of the grafted foot has not been excessive, even for a growing boy, and aside from packing his shoe where his toes were missing, he has had little difficulty and has participated in high school and collegiate athletics (Fig 157)

Full-thickness grafts may be used if desired, especially for small fresh surgical defects, the graft is usually obtained from the inguinal region.

After any grafting, the usual bulky pressure dressing is applied to the whole foot



FIG 164 Coverage of most of the sole of the foot in a Negro with a thick split-skin graft. The foot was frozen and then thawed out by the patient with hot water bottles with a resulting granulating open ulcer of most of the sole Subcutaneous fat and padding are intact so that a split graft sufficed for coverage. Note lack of metaplasia (split graft remains black and grows hair though the sole is white and hairless)

and the lower leg to obtain partial immobilization of the foot and the ankle the tips of the toes are usually exposed to observe circulation The grafts are dressed at the usual intervals and the patient is kept in bed with the foot elevated on a pillow for at least 2 weeks Then the foot is allowed to hang down for a few minutes at a time (with the pressure dressing in place) and this is gradually increased until a few days later when crutch walking may be allowed If the graft is on the sole the pressure dressing is not left off and full weight bearing is not started until between 3 and 4 weeks after operation A small sponge rubber pad may be used in the shoe under the graft for a time or even permanently if it seems best

The graft is kept lubricated for several weeks with cold cream but requires little other care In some instances there may be an annoying tendency to callus formation in the adjacent skin of the sole near the graft margin This callus may grow out and over lap the graft and become so hard that it acts as a chisel to cut or abrade the graft Treatment consists of paring down the cal lus as necessary and applying various soft en ing or keratolytic agents such as castor oil or salicylic acid preparations from time to time After some weeks months or years the callus formation may cease as mysteri ously as it started

LOCAL FLAP REPAIRS

Local or adjacent flaps are used when possible, but as there is little extra skin in the foot, and the plantar skin is not very flexi ble closing a round defect of any size in the sole can be similar to trying to close a knothole in a board Care also must be taken in mobilizing any flaps to avoid inter rupting important nerve or blood supply

Rotated flaps can be moved from "silent areas on the sole, such as the arch or behind the toes to weight bearing points and the donor area skin grafted This procedure is particularly useful for repairing defects from the removal of plantar warts (Fig 172) small deep scars or tumors and avoids a major cross-leg procedure Again nerve and blood supply should be considered care fully If the flap is long in relation to pedi cle width or if it has to be rotated 90° or more it is often safer to delay it by staged preliminary raising

The "stirrup flap is a double pedicled one to shift the arch skin forward to the ball or backward to the heel the pedicles are on the sides or the dorsum and are curved toward the direction of movement The blood supply is not overly good Some times it can be shifted as a direct flap but raising should be slow and cautious and if edge bleeding in the center is tending to



FIG 165 Split graft and local flap shifting to sole (*Top*) Foot after prolonged treatment, including radiation and tedious preparation of abdominal tubed pedicle flap (elsewhere) for wart of heel (*Bottom*) Repaired in one operation by wide excision, split-grafting part, and shifting local flap from side of foot over part The distant tubed flap was not needed and was excised and discarded Excellent final function

vanish, it is better to replace it and do a staged procedure The final disposition of the pedicles may require the sacrifice of some normal skin, and this flap is not as "mobile" as it might be thought to be

Filleted toe flaps are utilized occasionally but such amputation procedures should be avoided whenever possible

The donor area of local flaps is usually covered with a split-skin graft at the same operation, and the after-care is the same as noted under grafts The outer keratinized layers of a plantar flap are dead or semi-dead, so that healing occurs only and slowly in the basal layer, for this reason, skin sutures are not removed until 2 weeks or longer.

PERMANENT PEDICLE BLOOD-CARRYING FLAPS

Permanent pedicle blood-carrying flaps to increase vascularity in ischemic areas are of great service in repairing severe radiation lesions or defects resulting from resecting dense deep scars (Figs 165, 166 and 167) These may be rotated flaps in the sole, or over the dorsum, or dorsum to sole flaps or even stirrup flaps The single pedicled flap is more generally useful, and a delayed flap is generally safer

CROSS-LEG FLAPS

When a distant flap is required, the cross-leg flap is most often the best choice These flaps, the same as grafts, do not give a nor-



FIG 166 Repairs over Achilles Tendon (*Left*) Old ischemic, broken-down scar over heel cord Not enough blood supply for resurfacing with free graft here (*Right*) Repair by rotation of delayed permanent pedicle blood-carrying flap from side, and split-grafting donor area (The final photo is 11 years after the repair, with persistence of good function)

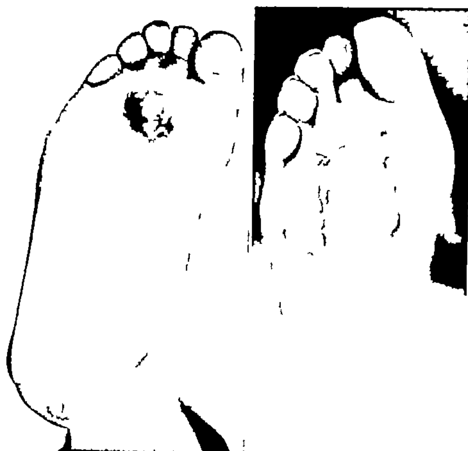


FIG 167 Perforating ulcer and repair with permanent pedicle, blood carrying flap This area was too ischemic for a free graft but the donor site was split-grafted

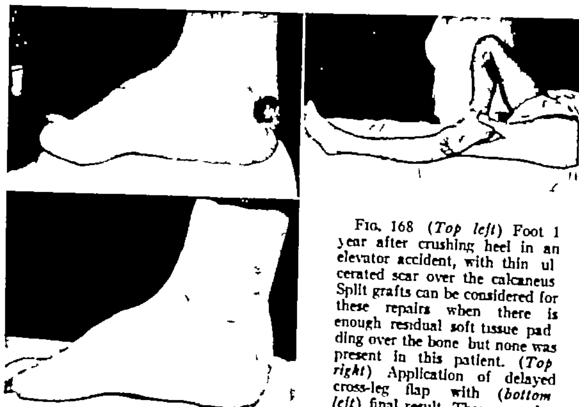


FIG. 168 (*Top left*) Foot 1 year after crushing heel in an elevator accident, with thin ulcerated scar over the calcaneus Split grafts can be considered for these repairs when there is enough residual soft tissue padding over the bone but none was present in this patient. (*Top right*) Application of delayed cross-leg flap with (*bottom left*) final result. These cross-leg flaps are best obtained from the thigh.





FIG 169. Direct cross-leg flap repair (*Top, left*) Defect of 40 years' duration from a railroad accident, with the patient off duty for 30 years (*Top, right*) Result following 2 operations to transfer direct cross-leg flap, up and down in 3 weeks (*Bottom*) Final appearance of the donor leg



mal sole, because the fat does not change into the compact fine-grained structure characteristic of plantar fat, and the skin does not undergo metaplasia into a thick keratotic sole However, the cross-leg flap may be the best substitution possible in some cases, and with care it will provide a satisfactory permanent walking surface (Figs 168 to 170)

One major disadvantage is the cumbersomeness of the procedure and the extreme manual labor required of the surgical team However, the foot is out on the end of a long peninsula, and getting a distant flap out there by any means will always be cumbersome

The cross-leg position is poorly tolerated by most patients over 40 years of age, and in older patients it is usually impossible Joint fixations, arthritis, or other disabilities may also preclude its use It is important to be certain that the patient thoroughly understands the procedure, and that he has the physical ability and mental fortitude to go through with it, before it is started

Direct cross-leg flaps are most useful and simple and are relied on when the requirements of the defect are such that a donor site can be arranged satisfactorily A short, broad pedicle is used, usually with the base of the flap applied along the outer side of the foot, rather than a long flat, or tubed, pedicle The process is much quicker and easier and more economical, and the repair is possibly somewhat better because the flap is made to order to fit the defect during the first operation rather than by separate procedures These flaps require that the foot can be brought all of the way to the donor site, with the patient being able to tolerate the position throughout fixation

Sites of flaps for certain defects can be more or less standardized, but each defect is an individual problem The best site is the one the patient finds the most comfortable through practice, taking into consideration the avoidance of the knee joint and

important nerves and vessels Large flaps are usually best obtained from the anterior or the anterolateral, or the lateral surface of the lower thigh

At operation a pattern of the foot defect is marked out on the selected donor site, and the patient is covered with stockingette below and above up as far as the lower ribs The short broad direct pedicle flap is cut around down to the fascia and slowly dissected up at that level, checking the blood supply of the central outer edge from time to time Then it is hinged back and the circulation finally checked If adequate, the foot defect is prepared, and the foot is brought up into place on the flap and anchored, either with or without dressing the donor site in a free graft at this time. The shape of the flap will often be that of the longitudinal half of an ellipse The edges of the foot defect are dissected up quite thickly, and the flap is attached to the foot almost entirely by interrupted fine subcutaneous catgut sutures, though a few silk sutures may be used in the skin where necessary Grease gauze is applied, then surgical waste and a pressure dressing is wrapped around the flap, the foot and the ankle and the adjacent thigh, an assistant holds the leg above the foot throughout to maintain the exact position The position will usually be most comfortable if the knee on the recipient leg is held so that the hip is neither adducted nor abducted but about midway between

Felt or sponge rubber pads are applied



FIG 170 "Heel-and toe" cross-leg flaps raised directly by H-shaped incision and applied simultaneously detached 3 weeks later (*Top left*) Freezing injury with loss of toes (*Top right*) Result (*Bottom left*) Method of fixation (*Bottom right*) Foot attached with split graft on donor area Entire transfer in two operations one on and one off Patient was cared for at Valley Forge Hospital

over the bony prominences of the pelvis, the knees, the fibular heads, all four malleoli, and over the sole of the foot on the donor side A double hip spica plaster cast is applied all around from the lower rib cage to the toes of both feet, with suitable plaster reinforcements It is often helpful to lay a length of wooden broomstick outside the fresh cast, across the top of the knee of the recipient leg and down across the front of the upper part of the donor thigh, and then incorporate this with plaster and join it to the cast This helps stabilize the position between the two extremities and can also be used as a handle to lift the patient Some experience in working on an orthopedic service in the days when hip spicas were common is probably the most useful adjunct of all at this particular stage

Finally, after the cast has hardened for 20 or 30 minutes, a window is cut over the flap, so that it can be removed from time to time for inspection of the flap, then it is taped back in place (Fig 168)

There are schemes whereby specially made splints of plexiglass or other materials can be prepared beforehand, and these may be worthwhile where a quantity of cross-leg flaps are to be done

In any event, it is important that the condition of the flap and the functioning of both peroneal nerves be checked frequently during the first few postoperative hours and occasionally thereafter

Lower leg flaps can be crossed to smaller defects on the foot (Fig 169), and are somewhat more comfortable However, large flaps cannot be obtained from this source, and their blood supply is more precarious, so that they are more frequently delayed They are obtained from the fleshy part of the calf, medially, posteriorly, or laterally, but *never* from over the tibia It is also well to leave sufficient covering over the fibula, and to avoid the weight of the recipient foot or ankle pressing down on the fibula, one of the feared complications can be necrosis of the underlying fibula in transferring these flaps

Pocket flaps are made by simply opening an area on the leg, through a single long incision, usually made transversely below the knee, and undermining a pocket These are for the end of the foot when it can be implanted into the pocket through the single opening The procedure was developed at Valley Forge Hospital and used there extensively in military services with great saving in time These flaps were often called "slash" flaps, but "pocket" seems to be more appropriate

Double heel and toe flaps are utilized along the side of the knee for replacing the front and the back of the foot in a single direct flap procedure A pocket flap can be used for the toe and a direct flap for the knee These flaps may seem to be bizarre for civil needs but they are not bizarre in military plastic surgery, where resurfacing of the foot is a constant problem (Fig 170)

Delayed flat flaps are used when a short broad pedicle is not feasible The usual procedure is to open the long axis in two parallel lines, undermine between, and close the incisions The distal end is cut across secondarily in 3 to 10 days and closed, usually under local anesthesia The delayed flap is transferred a week or so later, when there is no swelling, induration, or redness, and no suggestion of inadequate circulation through the pedicle

Tubed flaps are rarely used but are necessary occasionally when for some reason the foot cannot be brought to the donor site The tube can be raised along the inner side of the thigh with the pedicle below, at the knee, and the flap turned over to extend down toward the recipient foot (Fig 77). These are usually delayed Parallel incisions are made along the long sides, and the cut sides of the flap are sewed together to make the tube The raw donor area underneath is closed by undermining and suturing, or by split-skin grafting If a large flat "pancake" is to be used on the upper end of the tube this is delayed secondarily, as is the end of a flat flap There are several methods of determining adequate circulation in a tubed

flap the best one of which, as learned by experience, is the finding of no redness swelling, or other sign of failing circulation Chemical methods depending on injections and determination of absorption of test materials, or temperature change methods, may give information about the tube proximal to the tourniquet on one end but will not help for the flat end or "pancake" if one is used with the flap The procedure for combined flat and tubed pedicle flaps is about the same as that described for utilizing a flat area on the end of a tube The tube in all of these instances is for ease of position and transfer, especially if the pedicle has to be twisted

Cross-sole and cross foot flaps are mentioned only to repeat that in a large series they might result in more added disability than benefit

The detachment of flaps from a cross-leg usually can be done in 18 to 21 days, depending upon the broadness and the firmness of the attachment to the recipient foot Frequently, it is safer to cut one quarter across the pedicle from each side under local anesthesia and leave the central half of the pedicle intact for another day or two and then divide it if everything appears to be all right If there is question, the last portion of the pedicle can be compressed between rubber-shod clamps for 30 minutes and the adequacy of the recipient circulation determined before the final detachment is done The final detachment is usually done in the operating room under general anesthesia after which the cast is removed and the patient is given a soap-and water bath on the operating table The pedicle remnant on the donor side is trimmed and sutured down in place, and if the remaining donor area has not been grafted and is reasonably clean it is grafted at this time The raw end on the foot may be trimmed and sutured in place in most instances but if there is a tail hanging that has to be wrapped further around the foot it may be as well to postpone this for a few days or a week After the foot is dressed the joints in both lower extremities may be gently put through full range of motion under anesthesia

Donor sites of flaps may give difficulty if the sites are not selected advantageously and cared for properly Patients have been seen who have had as much difficulty from the donor site as from the original lesion As mentioned before, the donor sites may be skin grafted at the time the flap is transferred, but this is in no way necessary, if they are dressed often and kept clean Sometimes the procedure is carried further so that both the donor site and the undersurface of the pedicle are skin grafted at the time of transfer This may be advantageous in some instances for simplicity of care but is not routinely necessary if adequate dressing care can be given Allowing the wound to granulate up before grafting may result in a smoother final donor site and serious infection and fibrosis do not take place around a defect just because the donor site and pedicle of a flap have not been grafted

JUMP FLAPS

If for some reason a local flap or a cross-leg flap cannot be used, and a flap repair is necessary, an *open jump flap* from the abdomen carried along the forearm, may be the method of choice A large direct flap from the abdomen may be broadly attached along a considerable length of the forearm detached in 14 to 18 days and transferred secondarily to the foot or the leg. Of course the forearm on the other side from the foot or the leg is used and positions are tested beforehand A variation of this method includes folding the flap on itself after detachment from the abdomen, when a time interval is to elapse before the flap is secondarily transferred to the foot or the leg

Tubed flaps from the abdomen to the wrist and thence to the foot or the leg, are subject to more circulatory troubles than open jump flaps and there seems to be very little reason for using them Many patients have been seen who give stories of months or years devoted to stages of this procedure

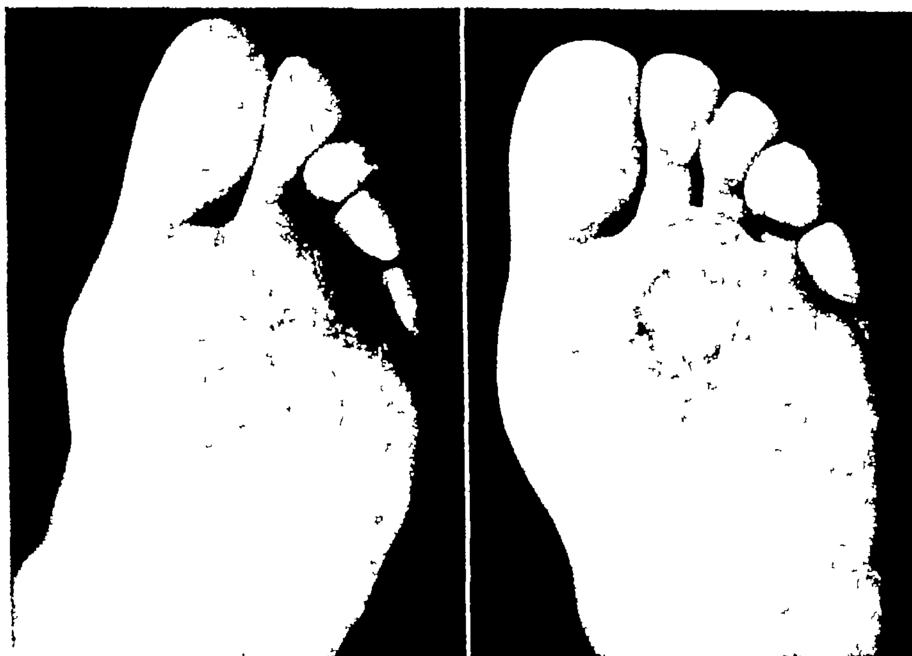


FIG 171. Wide excision of a plantar wart resistant to radiation Skin edges on either side were undermined, and little flaps of plantar fat were obtained and brought together over the wound with No 000 silk sutures to replace padding over the head of the metatarsal A thick split-skin graft was applied with stent fixation (over a pad of cotton waste) The patient has quite satisfactory walking surface with no more pain.

FIG. 172. Result of repair after excision of plantar wart at the base of each great toe The wart on the right toe was larger and deeper, so that it was necessary to bring in some additional padding by means of a small direct flap from underneath the second toe and split-graft the donor area. The wart on the left foot was smaller, so repair was the same as for the patient in Figure 171

with final failure. Surprisingly enough, many of them have had small defects which were then repaired immediately in one operation with a free skin graft, or with a local permanent pedicle flap

CATERPILLAR FLAPS

Caterpillar flaps, which are tubed flaps migrated end-over-end and endlessly, are mentioned here only to suggest that they never be used here or elsewhere The same reasons apply as just mentioned under tubed jump flaps though with more certainty

PLANTAR WARTS

Plantar warts are the reason for most repairs of the sole (Figs. 161, 171, 172) It is difficult for most patients and institutions and some medical echelons to understand how an insignificant thing like a wart can necessitate so much trouble and surgical work An answer can be that the wart does not amount to anything but its location does, and, to repeat, once the sole is open disability exists until the sole is healed free of trouble, and especially free of the wart A painful wart might be likened to a cinder in the eye or a tack in a shoe, not much in themselves but exceedingly painful and disabling

Added to the wart may be scarring from electrofulguration or from acid treatments, or surgical excisions worse, there may be a radiation lesion with or without malignant change Patients have been seen who from the results of these have been bedfast for months, or unable to walk decently for years, with stories of unremitting prolonged pain and loss of morale and jobs

The surgical problem may be twofold (1) to remove the lesion and its complications, and (2) to build a satisfactory repair

For repair of warts, scars and radiation lesions in the center of the foot, simple linear excision and closure may suffice if the area is not too large Otherwise a free skin graft may be used if sufficient pad is left to support it or if small fat flaps can be mobilized underneath the surrounding skin and swung together over the center of the wound to make enough padding If this is not possible, a local flap may be needed, but it should not be swung from adjacent weight bearing surfaces over the first or the fifth metatarsal heads, but rather swung back from under the toes, or forward from the arch Such a flap may have to be delayed

Warts, scars or radiation lesions over the first or the fifth metatarsal heads or over the heel are not excised and closed by direct



Fig 173 "Trophic" ulcers in an anesthetic foot. The heel ulcer has been excised and covered with a split graft. The ulcer on the ball of the foot has been excised and covered with an adjacent double-pedicled flap to supply enough padding under the head of the metatarsal. The donor area has been split-grafted. There may be recurrences elsewhere on the foot requiring similar treatment but the only other possibility is amputation This patient has worked 4 years as a railroad fireman since this operation was done

suture, as this may leave a painful scar. Flaps are usually rotated in from the center of the ball, or behind the toes, or from the arch; in the case of the heel, a flap may be used from the arch, or from the side of the foot The flap donor sites, of course, are covered with a free graft

A plantar wart, insignificant as it seems may require major surgical planning, meticulous surgical execution and prolonged surgical aftercare for a permanently satisfactory result

TROPHIC AND PERFORATING ULCERS

A better term for these might be "anesthetic" ulcers, as they occur on the soles of anesthetic feet and perforate deeply due to continued pressure and lack of sensation There is very little evidence that there is any "trophic" element involved

They are likely to occur on any anesthetic foot and may be seen on patients with spinal cord diseases such as syringomyelia, combined system disease, etc , following spinal cord injuries, and following peripheral nerve injuries including most especially severance of the posterior tibial nerve

The prognosis is generally poor If there is any possibility of alleviating the anesthesia and restoring any degree of sensation, treatment should be directed toward that goal first

However, local treatment may be necessary to prevent loss of the foot, and it is worthwhile undertaking it if it is thought that the patient will co-operate in giving the foot proper care afterward (Figs 167 and 173).

Local treatment most often consists of complete and deep excision of the ulcer down and around to healthy bleeding tissue in the depths and on all sides. Repair is carried out most often with a *permanent-pedicle local flap*, if there is any possibility of carrying functioning sensory nerve filaments into the area by this procedure it should be planned in that manner. The most important facet of treatment is instructing the patient in the future care of his foot. He must understand that prolonged pressure and ischemia is the cause, and that he must get off the foot completely whenever there is the tiniest break in the surface, and stay off until it is solidly healed A layer of sponge rubber in the bottom of his shoe may help, and he must train himself to feel in the bottom of the shoe every time he puts it on, to be certain there are no wrinkles in his socks, to shift his weight constantly back and forth while standing, and to take off his shoe and sock and look at the bottom of his foot every 6 hours when he is up and about He must also keep his weight down to average or below-average levels With these precautions, a satisfactory surgical repair may result in a foot that functions well for many years (Fig 173), or even permanently, even though it remains anesthetic

OTHER FOOT REPAIRS

Other foot repairs are described in Chapter 30, "Restoration of Defects from Farm, Traffic and Industrial Injuries." Chapter 32, "Surgical Repair of Radiation Injuries and Atomic Burns," and Chapter 33, "Skin Grafting in Military Plastic Surgery."

22

Repairs of the Face

On the trunk and the extremities a stable surface with sufficient skin for free movement is most important in the repair, with appearance secondary On the head and the neck, the amount of skin to be transplanted may be much less, but appearance is of prime importance so that greater finesse is required in the work. For small repairs, full thickness grafts from the clavicular area are usually best, with postauricular grafts being a second choice. For larger repairs, very thick split grafts of good texture often can be obtained from the lower anterior chest wall (Plate 4)

All border bluish scar epithelium should be excised with precision and the grafts carefully fitted into place Fine suturing is done meticulously and long edge sutures



FIG. 174 Lupus with superimposed radiation dermatitis and ulcerated squamous carcinoma in lower anterior edge. Repaired in one operation by excision and coverage with single split graft. This type of lesion may recur eventually but the patient gets immediate relief lasting many years from the operation and the presence of radiation dermatitis or carcinoma makes the procedure obligatory



FIG 175 Total resurfacing of face and neck, using a separate free skin graft for each feature, though several nonadjacent features can be worked on at the same time. The patient sustained burns in war and was cared for at Valley Forge General Hospital.

frequently are placed for local tie-over dressings, in addition to outside general pressure dressings The face is mobile, irregular in shape, and presents difficulty in counterpressure, so that complete takes of grafts and flaps are difficult but highly important for the best possible final appearance (Fig 174) Pinch grafts, of course, are not used on the face

NECESSITY OF SEPARATE REPAIR OF DIFFERENT FEATURES

The face is not a single unit but a group of individual features situated adjacent to one another Each may have a specific function such as seeing, smelling, eating, etc, and each plays its own separate part in appearance and in emotional expression When two or more features are damaged, the repair must be separate and individual (Figs 175 and 176)—not *en masse*

For instance, if a group of facial features are covered simultaneously with one large flap, or one large graft, there is the danger that they may lose their separate identity and be bound together into one unnatural mass This may be ameliorated by later separating operations, but it may be impossible to overcome this gross defect in the original plan of the repair.

Perhaps the worst example is the "visor" flap, in which a flap with bilateral pedicles is swung down from the forehead or up from the neck or the chest to cover the whole middle third of the face, including all 4 eyelids, 2 cheeks, the nose and the upper lip Holes are cut in the proper places, but the whole thing is apt to look as though the patient had been hit in the face with a blob of pie dough The patient may feel that he is behind an inert "flesh mask," and that he is carrying out his movements and expressing his emotions behind this prosthesis which is separating him from the world in front

Occasionally, patients will be seen with

PLATE 4



(*Top left*) Extensive warty hairy melanotic nevus of face. (*Top right*) Excised and split grafted in one operation Free skin grafting on the face is about the same as elsewhere except that more finesse and attention to details are necessary to get complete takes throughout and smooth margins



Final front appearance of the patient shown in Figure 328 including reconstruction of the axilla and the neck.

widespread facial cancers, radiation burns, or raw thermal burns in which immediate simultaneous coverage is a necessity, so that the surgeon has to make the best of the situation and try to separate the features later When there is a choice, however, it is best to repair individual features separately However, features which are not adjacent often can be repaired in the same operation such as doing both eyelids on one side along with the cheek on the other side etc.

In general, separate pieces of skin should be used for upper eyelid lower eyelid, nose cheek, upper lip, lower lip, chin forehead and neck (Figs 175, 176 281, 285 and 297) Any two or more nonadjacent features can be covered at one operation, except that it is usually possible to cover both eyelids on one side at one time with resultant independent function of each

FLAPS VS GRAFTS IN FACIAL REPAIRS

Repairs of the face more than in any other region require the use of pedicle flaps but free skin grafts can be used in many instances and are sometimes preferable to flaps (Fig 174)

Where the loss of a feature, such as the whole or part of the nose has occurred by trauma rather than a burn a more limited clean-cut deformity is left, and enough good tissue is available for the best possible repair (Fig 74) However, burns of the face which destroy features are usually so extensive elsewhere in the region and even over the body that the best final repair cannot be obtained because of the poor tissue available for the restoration surrounding the damaged area. This may necessitate bringing in tissue from a distance, but the work should still be made as simple and straightforward as possible For instance direct flaps from the inner surface of the arm can often replace the laborious use of caterpillar or jump flaps Back flaps are avoided because of the excessive length of the pedicles poor circulation and generally coarse texture of the skin Forehead, neck and chest flaps can be used when available but these areas are often damaged with the face (Figs 177, 178 and 179)



FIG. 176 Profile views of patient in Figure 175 The literature is full of hypotheses as to how these might be done with a seeming reluctance to show successful completed cases. Free skin grafts are infinitely superior here as they are thin flexible and move in expression, whereas a large flap may tend to form a blobby fixed mask.





FIG. 177 Severe radiation dermatitis of a whole side of the face, with early malignant changes, the changes in the eye so marked and painful as to require removal The entire side of the face was excised and repaired with a huge chest flap, with the result shown at the right

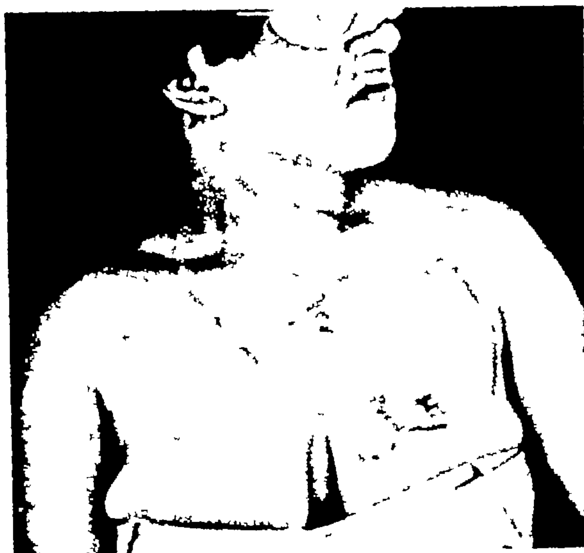


FIG 178 Stages in repair of the patient shown in Figure 177 (*Top, left*) Design of delayed chest flap which was prepared by several preliminary raising operations (*Bottom, left*) Excision of involved area of face (*Bottom, right*) Application of chest flap to face





Flaps are generally necessary for restoration of bulk or contour but when simple resurfacing is the requirement free skin grafts are usually preferable

A good free skin graft is thin soft and flexible enough that when it is applied to the surface of the facial muscles, or with only a thin layer of tissue intervening the graft will move with these delicate muscles and express the various emotions.

Even the best flap, however, is apt to be thick and stiff enough together with the lost movement in its own fat pad, that the muscles of expression move behind it without altering its shape very much If a separate flap is used for a single feature, however there may be some total movement of the whole feature The poorest place for satisfactory motion generally is in a flap reconstruction of an eyelid where the very



Fig 179 Use of a lined flap to cover a cavity (*Left*) Basal-cell carcinoma of the cheek extending into the antrum (*Center*) Appearance of the patient after one operation in which carcinoma was widely excised with the cautery a forehead flap was raised and a free full thickness skin graft was inserted under it for lining A probe is inserted into the parotid duct which is draining on the outside of the face (*Right*) Final appearance after swinging a lined flap down over the antrum and split-grafting the forehead. The parotid duct was put down into the mouth The patient remains well 6 years after the operation

delicate muscles simply cannot move the inert mass satisfactorily in little quick blinking, etc.

If an entire feature is to be covered with a flap or a free graft, it is best to do it in one piece and avoid separate patches within that feature.

Lined flaps are usually necessary for closing over large holes, such as cheek openings through into the mouth or the maxillary sinus (Fig. 179), or forehead openings into the frontal sinus

The raw burned face always presents a difficult problem (Fig. 297) The eyelids may be the most acute problem, to get them débrided, grafted and restored before there is damage to the globes If the facial burns are extensive, it may be necessary to cover large areas with single grafts, and then later put in small graft inserts to separate the various features If the split grafts prove to be unsatisfactory in any particular areas, they may be excised and replaced later as necessary with full-thickness grafts or pedicle flaps

Generalized skin shortening throughout the area of the face is not a rare occurrence in healed burns and is relieved by resurfacing the entire area of involvement in stages with free grafts (Fig 327) The fine muscles of expression may be covered by a thick mat of dense scar but may not be totally destroyed so that it is especially important to remove this deep scar in these cases The object is to get a loose but light and mobile covering over these muscles, often free grafts will do this better than flaps. In widespread involvement, each cheek, each lip, the nose, the eyelids, the forehead and the chin are done in separate stages, but two areas which are not contiguous can be done in one operation, such as the forehead and the lower lip, or a cheek on one side and the eyelids on the opposite side The "stent" type of fixation with surgical waste is used extensively on the face in almost all areas except the forehead, where it is not necessary

Full-thickness grafts are often preferred to split grafts because of their better texture and appearance (Figs 241 and 242), but split grafts should be used to cover all granulating or dirty areas (Fig. 297) After healing is obtained they can be replaced with full thickness grafts or pedicle flaps when this would effect an improvement in the appearance

SUPRACLAVICULAR SKIN GRAFTS

Small full-thickness grafts of good color and texture can often be obtained from the lower neck just above the clavicle Grafts from the back of the ears match the facial skin well in some patients, but prove to be too red in others

These full-thickness grafts from the neck and the clavicular region have been found to give superior results in the repair of many facial defects The amount of skin available is limited, but there is enough for eyelids, the nose and about the mouth (Plate 4, Figs 101, 186, 193 and 272)

Two main advantages are improved function and color The graft was first used on the lid, and many full replacements of the lid skin hardly can be distinguished at a distance of only 2 or 3 feet (Plate 8). The color is nearly always close to that of the normal face and is due to the good color of the neck skin, plus the good function that is possible, and to the actual extra thickness that these grafts have over the usual thick-split or full-thickness graft. None of these grafts so far has had to have pigment injection for color matching whereas, dead whiteness or darkness of other grafts often leaves much to be desired There is natural redness in the grafts not found in other skin and this redness is the reason for the match with the surrounding skin. (On a burned face that has healed to a dead white, these grafts give a noticeable contrast, although they are the closest to normal.)

The second advantage is softness and, therefore, function This function, of course, is of underlying muscles, but these grafts heal in so soft and have such thickness that the best kinesis of grafted areas can develop

This property again is best expressed in eye lid repairs, where hard, boardlike scars of gasoline and phosphorus burns have to be literally dug out of the lids and across from one eye to the other over the nose When these areas are covered with the neck grafts there is often a dramatic relief of scar fixa tion and return of softness and function

The good function is due to the thickness and the softness and possibly to the char acter of the skin which, in its natural habitat overlies a platysmal muscle This point has not been proved so far, but the result of an eyelid s being soft, of normal color, giving normal function healed in with practically no edge scar, in 2 to 3 weeks after grafting brings up the platysmal idea

Late function is excellent as there is mini mal contraction of the graft bed when these grafts are used (Figs 186, 193, 250)

The graft is usually superior in color and function to those from other preferred areas such as the mastoid and the inguinal regions.

The main areas for use are on the lids in the canthal regions about the ala over the nose and about the lips and the angles of the mouth As a rule flap repairs are con sidered for gunshot wounds, whereas, grafts usually suffice for burns However, about the lids if a bed at all suitable can be ob- tained by dissection of the scars, these full thickness grafts are used in preference to flaps and it is thought, with better results

Donor sites can be closed left open to granulate or grafted They may make trou blesome scars for a while but no permanent severe trouble has been seen Large scars would be objectionable in women but this does not preclude the use of small grafts

OTHER FREE SKIN GRAFTS

Larger full thickness grafts are sometimes taken from the lower abdomen the groin and adjacent portion of the thigh (Fig. 285) Very thick split grafts can often be obtained with the dermatome from the lower chest wall anteriorly and may have texture and color approximating that of a full thickness graft (Fig 307)

Injection of permanent pigments into the grafts may be desirable in some instances to bring about a closer color match (Fig 318) Secondary excision and readjustment of border scars will help at times to make the whole repair smoother

The possibility of closing small defects by undermining and suturing, either all at once or in stages, or by switching local flaps should not be forgotten but cannot be used when it would displace or distort features

Forehead

Defects in this area present a rigid, smooth bed which can contract only slightly so that thick split skin grafts can be used almost routinely with good results It is easy to get good pressure with a circular head bandage so that "stent" fixation is not nec essary (Figs 75 194 and 241)

Because of the rigidity of the bed, spon taneous healing of any granulating wounds in this area is unusually slow but may occur with some displacement of the hairline downward and the eyebrow upward In such instances, after removal of the scar, these features should be dissected loose enough to resume their normal positions before the graft is applied

Frontal sinus fistulae occasionally occur from osteomyelitis, injury or the removal of tumors These can be closed in most in stances by swinging in a local flap after making certain that the sinus has adequate drainage into the nose Rarely, a flap from a distance may be necessary

Burned dead bone (from fire, electricity or radiation) in the forehead or the temple areas may present difficult problems (Figs 92 93) In general it is often best to pre pare a local permanent-pedicle blood-carry ing flap, based on the temporal or supra orbital artery After it is certain that the flap is viable and will cover the defect, the dead bone is *removed* If it is thought that only the outer table is dead one can wait for partial sequestration or carefully drill multiple holes just through the outer table wait for granulations to appear and then



FIG 180. Burn contracture of cheek, outer canthus and supra-orbital area repaired in one operation with thick split graft

chisel out the intervening fragments If both tables are dead, a perforator opening is made through to the dura, the latter is separated from the undersurface all around with a dural elevator, and the dead bone is then rongeured out until live, bleeding bone is encountered on all sides Then the flap is rotated into place and fixed, and the donor area is skin grafted If the final bony defect is large enough some months later to warrant it, a bone graft may be slipped in under the flap (Fig 268)

CHEEK

The facial muscles normally attach to the skin and give emotional expressio[illegible] if any muscle power has been lef[illegible] much more evident if covered [illegible] skin graft than if covered by [illegible] (Fig. 180) This may not be [illegible] still photographs but is quite a[illegible] actual observation of the patien[illegible]

In deep cheek[illegible] mus[illegible] lost or marke[illegible] so th[illegible] ness provide[illegible] give[illegible] tour than th[illegible] graf[illegible]

Full-thick[illegible] wi[illegible] fistulae into [illegible]he[illegible] sinus require[illegible]g as[illegible] covering In [illegible]orehe[illegible]

will provide the most suitable covering If the opening goes into the sinus, or too much of the buccal mucosa has not been lost, the flap can be lined while still on the forehead with a full-thickness free graft (Fig 179) When most of the buccal mucosa is gone, it is important to restore it with a flap in order to get a new lining that is soft and resilient enough to allow full mouth opening In this instance, the lining usually has to come from a neck or chest flap The covering may be provided by a forehead flap or may come from the same neck or chest flap In the latter instance, it is better to fold the end of the flap in under for lining while it is still down on the neck or the chest and to keep a pressure dressing on it for 2 or 3 [illegible] swinging the double-surfaced [illegible] up into the defect. In all [illegible] is necessary to be certain [illegible]ing parotid duct is turned [illegible]o [illegible]ing a flap [illegible] burns about [illegible] of a beard [illegible]ion and [illegible]s per[illegible] [illegible]th [illegible]

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surface may occur and cause deformities of the eyelids the nose and the mouth and again the restoration consists in doing the opening in the contracted area and resurfacing with suitable tissue (Fig 327)

LIPS AND MOUTH

The most usual burn deformity of the lip is eversion or ectropion and often the restoration can be done in one operation by opening the deformity to allow the vermilion to go back in place and inserting a free full thickness graft cut to pattern. Supraclavicular grafts are especially good for this purpose. In the lower lip it may be necessary to extend the graft upward and outward beyond each corner of the mouth, even cutting into normal skin to do so if necessary so that the upper border of the graft has external superior anchorage on either side and can act as a "hammock" to hold the vermilion up in place The "stent" type of fixation is used, with over-all pressure from long strips of Elastoplast The border of the "stent" adjacent to the mouth can be covered with zinc-oxide ointment or a silicone waterproofing material, and then narrow strips of Elastoplast put directly on the vermilion

Burns of the vermilion of the lips with circular contracture resulting are difficult to relieve At times it is the concomitant loss of skin just adjacent to the vermilion all the way around that is the worst factor in producing this purse-string effect. Often a good way to begin is to resect the scar, stretch the base out as much as possible and insert a free supraclavicular graft or else one from behind the ear This requires careful dissection and fixation of the graft but the results may be gratifying in function and appearance close to normal after only one or two operations If there is still lack of vermilion, sometimes flaps of mucosa can be swung out and down from the insides of the cheeks for repair Some additional full thickness openings may have to be done at the corners of the mouth in some patients (Figs 270 271 and 272)

Full thickness losses of the lip if extensive require restoration with pedicle flaps Usually Abbé or Estlander types of vermilion bordered cross-lip flaps are used, though occasionally it may be necessary to bring in flaps from a distance (Fig 82)

Extensive mucosal losses in the mouth may occur from electrical (cf Chap 31) or chemical burns, or from cautery destruction of cancer In most instances the scar should be opened to give complete relaxation and the resulting raw area covered with a split skin graft put in over a dental wax mold of the area Interrupted, long silk sutures are put in about every centimeter around the edge of the defect, the graft-covered mold (raw side out) inserted and the sutures tied snugly over the mold Fairly thin grafts from a nearly hairless area should be used. These grafts take well and serve as a good substitute for mucosa but remain as skin and do not undergo metaplasia into mucosa (Fig 326)



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Cheek

The facial muscles normally attach to the skin and give emotional expression and, if any muscle power has been left, it will be much more evident if covered only by a free skin graft than if covered by a thicker flap (Fig 180) This may not be discernible in still photographs but is quite apparent upon actual observation of the patient (Fig 327)

In deep cheek losses, the muscle action is lost or markedly impaired so that the fullness provided by a flap will give better contour than the usual free skin graft

Full-thickness cheek losses with large fistulae into the mouth or the maxillary sinus require restoration of lining as well as covering In many instances, a forehead flap will provide the most suitable covering If the opening goes into the sinus, or too much of the buccal mucosa has not been lost, the flap can be lined while still on the forehead with a full-thickness free graft (Fig 179) When most of the buccal mucosa is gone, it is important to restore it with a flap in order to get a new lining that is soft and resilient enough to allow full mouth opening In this instance, the lining usually has to come from a neck or chest flap The covering may be provided by a forehead flap or may come from the same neck or chest flap In the latter instance, it is better to fold the end of the flap in under for lining while it is still down on the neck or the chest and to keep a pressure dressing on it for 2 or 3 weeks before swinging the double-surfaced end of the flap up into the defect In all these repairs, it is necessary to be certain that any functioning parotid duct is turned into the mouth before attaching a flap

One of the worst features of burns about the cheeks in men is the presence of a beard which may cause continued irritation and even deep chronic infection if the hairs persist in turning in and being covered with epithelium It may even be necessary to remove large areas of skin so affected and cover them with free skin grafts

Generalized skin shortening of the cheek

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Repairs of the Eyelids and the Orbit

GENERAL CARE OF THE EYES

In all burns about the eyes, an ophthalmologist may be of great help in caring for the cornea and vision and in recommending therapy Early, frequent and careful cleansing of the whole area is done, and extreme care is taken that no crusts come in contact with the cornea This, with the copious use of bland or antibiotic ointments, has proved to be a safe plan of treatment

Anesthetic ointments are not usually used here If there is any complaint of scratching or pain, the dressing is opened immediately, the conjunctival sac is washed out with saline, the cornea is inspected, all lashes are turned out, ointment is reintroduced, and the lids are closed If relief is not complete, an ophthalmologist is called

At operation, care is taken to drip saline *on the eye from time to time and prevent* any drying of the cornea It is a rule not to touch the cornea with gauze, wet cotton, or anything else; this prevents many postoperative troubles

BURN ECTROPION

Burn ectropion of the lids usually can be corrected in one operation with free grafts put in place after the deformity has been freed by careful dissection (Plate 2, 8, Figs 183, 184, 185, 186) Most everted lids have enough mucosa left to allow for protection of the globe if the skin covering can be obtained The repair is made by opening carefully the junction of the everted mucosa and skin, turning the mucosa as a flap toward the globe and then covering the whole raw surface with a thick split graft or full-thickness graft or occasionally a small direct pedicle flap from the forehead or the temporal region Full-thickness grafts from the *supraclavicular* area produce the best results here because of their softness and mobility, in addition to their good texture and color (Figs 181 and 182)

The free grafts may be held in place by using a local "stent" type of fixation with the long edge sutures tied over surgical waste, and then an over-all pressure dressing wrapped around the head The edges of the lids may be sutured together for protection of the cornea, or if the deformity has been marked and of long duration, a surgical adhesion can be created between the tarsal borders and left for several weeks or months to keep the new graft up in position and to avoid contracture of it On the lower lid, it is at times advisable to carry the graft well up into the inner canthus medially and out laterally and upward beyond the outer canthus, even at the expense of opening normal skin The upper border of such a graft tends to support the tarsal border and hold it up against the globe This is practically a necessity when a flap is used, as otherwise the latter by its own weight might hold the

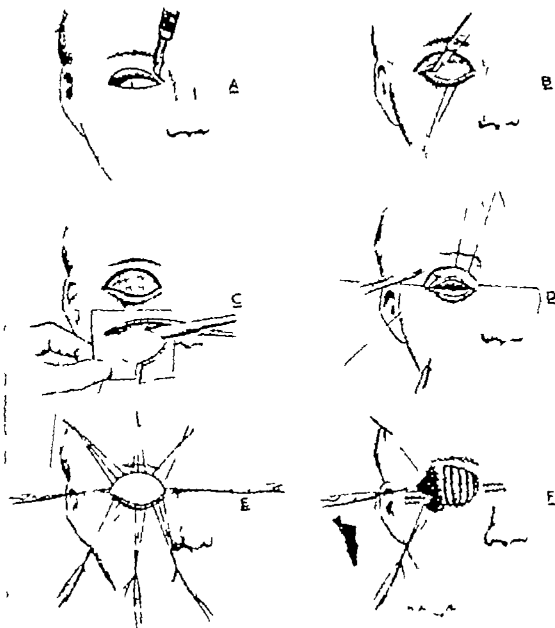


FIG 181 Contracted area opened surface and deep scar removed as necessary, to allow a little more than normal expanse Where pressure alone cannot be relied on—as on the lids—the fixation is obtained and the proper opening of the area maintained by tying the long edge sutures over a pad of cotton waste after first covering the graft with fine mesh grease gauze (Brown, J B and Cannon Bradford Ann. Surg 121 639)

tarsal border down and away from the globe

In general shortening of the skin of the face or the scalp the lids may be pulled away from the globe and the eyes even held open The correction of this constitutes a rather simple premise for all reconstructive surgery that is to open the contracted area dissect back the edges and fill in the resultant defect with normal suitable skin

CONJUNCTIVAL DEFICIENCIES

When there is lack of mucosa its replacement with free grafts of mucosa from the mouth should be considered as the

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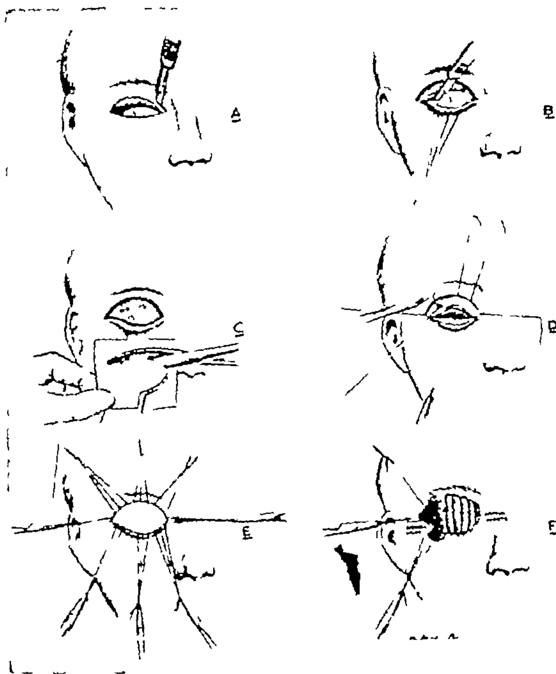


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bulbar conjunctiva reacts badly to skin in apposition to it These grafts are carefully dissected from the inner surface of the cheek with a scalpel, removing the entire thickness of mucosa, but trimming away any adherent mucous glands on the raw surface of the graft The graft may be put in over a tiny wet cotton or paraffin mold with fine, long silk sutures tied over it for "stent" fixation and the conjunctival sac then filled with petrolatum

In dealing with a symblepharon, it is usually better to start the dissection at the lid margin and continue until all available conjunctiva is shifted over onto the globe, so that the raw surface to be grafted is on the inside of the lid only It is also advantageous to switch local flaps of conjunctiva



FIG 182 Pattern of celluloid or other material traced on the neck with a pen and 5 per cent methylene blue Assistants stretch the area taut to facilitate removal of the graft which is held with the fingers to avoid forcep marks The wound is closed in layers with fine sutures (Brown, J B., and Cannon Bradford: Ann Surg 121 639)



FIG 183 Severe ectropion of all 4 lids with marked conjunctivitis and global irritation Repair of all lids with thick split grafts, doing one set of lids (upper and lower) at each operation The patient still needs a little more skin in the right inner canthus



Fig 184 Repair of burn contracture of upper two thirds of face, with free skin grafts First operation release of ectropion of both lower eyelids with supraclavicular grafts and resurfacing entire forehead with split graft Second operation resurfacing both cheeks with split skin grafts. Third operation free scalp grafts to make both eyebrows and resurfacing of nose with split graft.



Fig 185 Small eyelid repairs and adjustments may be the most difficult This one required (1) restoration of the upper lid and the outer canthus with a supraclavicular graft (2) readjustment and realignment of eyebrow fragments and (3) excision and readjustment of forehead and cheek scars. Result shown some years later

when possible, so that the lid just in front of the cornea is covered and the graft is on the medial or lateral portion of the lid These mucosal grafts usually take quite well, but have a tendency to shrink considerably, and their application always presents some hazard to the cornea, so that entirely satisfactory cases are much rarer than the literature might lead one to believe

ORBITAL REPAIRS

When the globe has been removed and a contracted socket is present, restoration of lining to permit wearing of a prosthesis should be considered if the lids are intact or nearly so Small deficiencies of lining in either the upper or the lower sulcus can be restored occasionally with mucosal grafts, but there will be marked shrinkage Larger deficiencies are restored best by wide dissection until a wide sulcus above and below is created and a socket at least twice as large as the prosthesis is obtained This new socket is then lined with a thin split graft (as hairless as possible) put in over a dental wax mold or a ball of iodoform gauze, and the lid margins temporarily sutured together with a pressure dressing on the outside In 5 days, the lids are opened, the excess graft is trimmed off, and the packing is changed then and every 48 hours thereafter The prosthesis may be fitted in about 2 weeks and usually functions satisfactorily, though there is a tendency for the socket to be dry and require frequent cleansing (Figs 187 and 188)

Discharge from grafted sockets is a well-known problem However, the mucous comes from the mucosa in response to small flecks of irritating sebum from any skin graft present Thus, the problem is most severe when there is a small amount of skin present with a large amount of mucosa, there will be less discharge present when



Fig 186 Airforce burn of midface (*left*) with adhesions across the eyelids on both sides The patient appeared to be blind (*Right*) After the adhesions were separated all 4 eyelids were recreated with supraclavicular grafts, the eyes proved to be all right with good sight. The patient also had resurfacing of the nose and all 4 canthal regions with split grafts, repairs of both ears, and restoration of most of both eyebrows with free scalp grafts. Cared for at Valley Forge Hospital Later, the patient was graduated in law



FIG 187 Lining eye-socket with skin graft (*Left*) Tiny scarred socket present following lye burn which would admit only a tiny thin glass shell that would not stay in. (*Right*) Socket dissected open and relined with large split graft put in over dental wax (stent) mold. A new large turnover plastic eye was fitted 2 weeks later The missing segment of the upper lid could be replaced with a tiny composite graft, but patient is satisfied.

there is a small amount of mucosa and a large amount of skin If the socket cannot be entirely lined with mucosa (as is often the case), and copious discharge is a severe problem it may be best to excise all remaining mucosa and line the entire socket with a single sheet of thin split skin graft. This latter socket may be excessively dry



FIG 188 Split skin graft to eye socket (*Top left and right*) Chemical burn with resulting small socket lined with a mixture of scar and mucosa discharging and too tender to tolerate prosthetic eye The patient had had several attempts at small mucosal transplants elsewhere (*Bottom left and right*) Result after resecting the mucosa and the scar completely creating a new sulcus above and below and lining the new large socket entirely with split skin graft. The discharge and the tenderness have disappeared. Only one operation was required.





Fig 189 (*Left*) Extensive invasive basal-cell carcinoma with only a small ulcer showing on the lower lid (near the outer canthus), but solid induration of both lids and complete fixation of globe due to orbit full of growth (*Right*) Growth (including entire contents of orbit and both lids) removed in one piece The bony orbital rim exposed was cooked with surgical diathermy and later separated

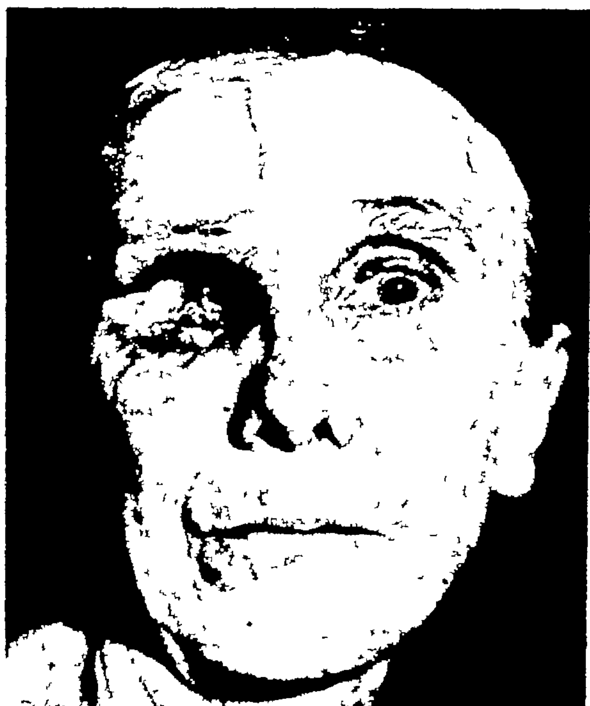




Fig 190 (*Left*) Appearance of the patient in Figure 189 3 months later after the orbit had filled in with granulations and become partly covered with epithelium. However, several fistulae into the ethmoid cells and one into the nose, were present. The forehead flap has been raised and is now ready for transference, after removal of the scar epithelium from the orbit (*Right*) Final appearance after 'blanking out' the orbit with the forehead flap The pedicle was returned, and the remaining defect on the forehead was covered with split graft. The patient wears spectacles with one opaque lens

and may require frequent cleansing and lubrication of the artificial globe with mineral oil but is much better than a socket which secretes profuse quantities of pungent mucous

Where there is absence of an eye and complete loss of one or both lids it is considered best to cover the whole orbital region with a blank flap rather than to try to reconstruct a socket and lids and hope to have a presentable prosthetic eye This latter procedure has been recommended and described, but entirely satisfactory cases are quite rare. The orbital obliteration is usually done with an island or direct pedicle flap from the forehead (Figs. 76, 189, 190 and 191)

EYEBROW REPAIRS

Eyebrows are important in appearance and can be replaced with strips of scalp transferred as free full thickness grafts or

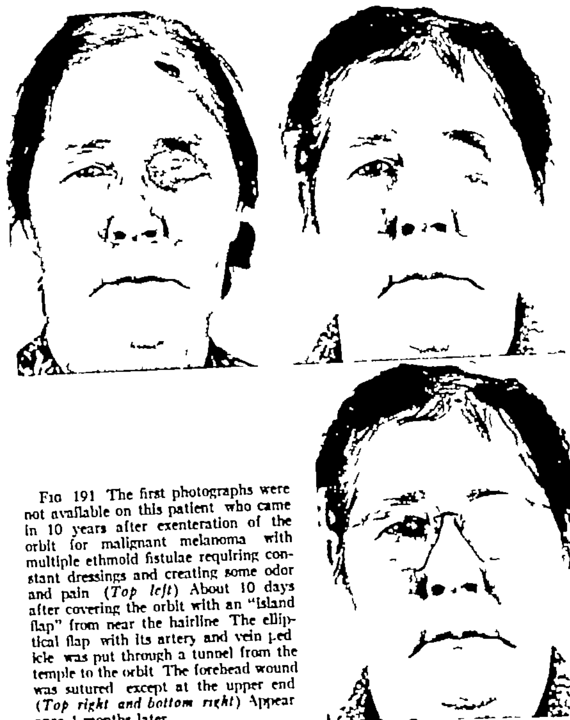


Fig 191 The first photographs were not available on this patient who came in 10 years after exenteration of the orbit for malignant melanoma with multiple ethmoid fistulae requiring constant dressings and creating some odor and pain (*Top left*) About 10 days after covering the orbit with an "island flap" from near the hairline The elliptical flap with its artery and vein pedicle was put through a tunnel from the temple to the orbit The forehead wound was sutured except at the upper end (*Top right and bottom right*) Appearance 4 months later

as island flaps (Fig. 327) Care should be taken in selecting the graft or flap so that the hair will be growing as nearly in the correct direction as possible The replacement is not perfect, as the scalp hair is coarser and tends to stand out from the forehead This can be remedied somewhat by allowing the hairs to grow to a longer length than normal and training them down with soap and eyebrow pencil for several months Free grafts are removed from the scalp just behind and above the ear and are cut through the entire thickness of the skin and subcutaneous fat The graft is then inverted over an assistant's finger or on a table, and each tiny grain of fat is dissected off with a fine thumb forceps and small iris scissors When this is complete, the undersurface of the graft will be covered with the bulbs of the hair follicles like a fine brush The graft is accurately sutured in place, and a pressure dressing is applied (Figs 184 and 186)

When only one brow is destroyed in a woman, and the other one is so thick that she plucks it anyway, a method can be considered in which the upper half of the normal brow is transplanted as a free graft inverting it of course The curve should not be inverted but can be modified by the direction of the opening incision, limiting its length, and the use of an eyebrow pencil and plucking afterward.

EYELASH REPAIRS

Eyelash replacement is still more in the realm of fancy than reality, but very thin strips of eyebrows can be transferred to the tarsal borders as free full-thickness grafts The direction and the curvature of the lashes is abnormal, however, and may attract attention almost as much as their absence would

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Repairs of the Nose

FREE SKIN GRAFTS

Many corrections can be done with free grafts when there has been a loss of only the surface skin Full thickness grafts can be used for small areas resulting from excision of skin carcinomas, nevi or port wine stains or for small burn scars or other traumatic losses of skin The best match is often obtained with skin from the lower neck but skin from the back of the ear may not be too red in patients with florid complexions The stent type of fixation may be used, or pressure may be applied by packing the inside of the nose to prevent its collapse and then applying grease gauze, a small pad of waste and an external aluminum splint on the outside In the preliminary dissection every effort should be made to avoid exposing bare bone or cartilage, though free grafts sometimes will carry over a few millimeters of these structures by lateral osmosis or growth of capillaries

Resurfacing of the entire nose is required in some patients (Figs 245 246, 247, 281 and 297) because of burns or radiation dermatitis In these instances, the damaged skin or scar is carefully dissected off without removing any subcutaneous tissue or exposing bare bone or cartilage However, an attempt is made to divide any subcutaneous scar bands that may be pulling the nostril borders up or otherwise deforming the nose The resurfacing is then done with a medium thickness split graft cut with a knife, as this graft can be made to conform to the contours of the nose better than a full thickness one (Figs 192 and 193) There is no reason whatever to use a flap for this re-



Fig 192 Resurfacing a burned nose with a free skin graft, rather than a pedicle flap frequently gives a superior result as shown above The patient also had the eyelid and the canthal areas grafted an eyebrow graft and ear reconstruction



FIG 193. Resurfacing of burned nose with soft supraclavicular free graft, and then composite graft to the nostril rim. (Brown and McDowell· Plastic Surgery of the Nose, St Louis, Mosby)



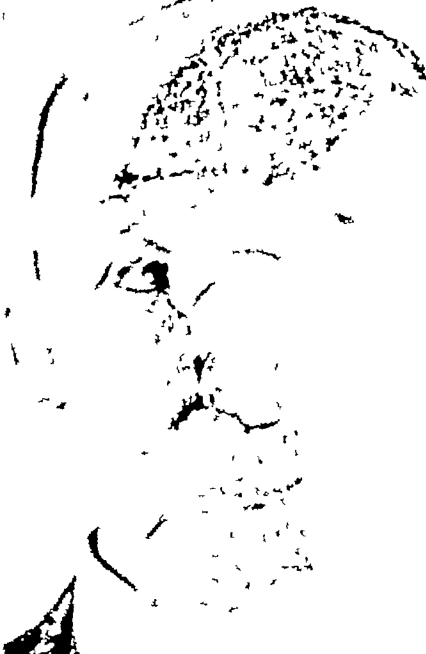


FIG 194. Reconstruction of almost the entire nose by means of a forehead flap, which was delayed in 2 stages Complete lining of the new nose is essential in this type of "Indian" rhinoplasty and was obtained partly by turning down the skin from the bridge of the old nose and partly by turning the end of the forehead flap up into the new nostrils to meet it The forehead was repaired by a split graft at the same time the pedicle was returned. L-shaped preserved [illegible] rtilage graft was inserted int[illegible] se to provide skeletal s[illegible]

surfacing flaps are indicated rather for bulk or filling out contour

Small perforating wounds of the walls of the nose usually result from removal of penetrating cancers. It is usually best to wait until these have been solidly healed sufficiently long so that there is little likelihood of recurrence of the tumor before starting the repair Reconstruction is most often done by inverting small flaps of skin from near the edges to provide the new lining, and then covering the area with a free full thickness skin graft or with a pedicle flap from the forehead the adjacent part of the nose or the cheek

Defects or deformities of the nostril border have been some of the most troublesome to correct If the niche is produced by the upward pull of a vertical scar without much loss of tissue it may be possible to correct it by a small "Z" plasty on the axis of the scar and going through the full thickness of the wall. When the tissue has actually been lost, the best correction is usually obtained by transplanting a free composite graft of the full thickness of the rim of the ear (Chap 13)

Composite grafts of skin and cartilage from the ear are most useful for repair of many nasal defects. They can be completed in one operation and often will yield a superior end result for small defects to that obtained by any flap The indications and the technic are discussed in Chapter 13

PEDICLE FLAP RESTORATIONS OF THE NOSE

Pedicle flap restoration is necessary if the whole feature or any considerable part of the framework is gone. The best flap is usually one from the forehead, as this skin has better rigidity, color and texture for the repair and contracts less than that from any other flap (Figs 75 194 and 195) The best noses can be made on men who are bald or have a receding anterior hairline so that a really large flap can be procured, in any event, a forehead at least 7 cm. high (from eyebrow to hairline) is essential for the construction of an entire normal-sized adult nose The flap is turned on a pedicle containing the supra-orbital artery and it is best to have the pedicle on the opposite side from the defect when only a portion of the nose is being replaced The distal half of the flap should contain the entire height



Fig 195 Profile views of the patient shown in Figure 194 before and after reconstruction



FIG 193 Resurfacing of burned nose with soft supraclavicular free graft, and then composite graft to the nostril rim. (Brown and McDowell Plastic Surgery of the Nose, St Louis, Mosby)



FIG 194 Reconstruction of almost the entire nose by means of a forehead flap, which was delayed in 2 stages Complete lining of the new nose is essential in this type of "Indian" rhinoplasty and was obtained partly by turning down the skin from the bridge of the old nose and partly by turning the end of the forehead flap up into the new nostrils to meet it The forehead was repaired by a split graft at the same time the pedicle was returned L-shaped preserved rib cartilage graft was inserted into the new nose to provide skeletal support



surfacing flaps are indicated rather for bulk or filling out contour

Small perforating wounds of the walls of the nose usually result from removal of penetrating cancers It is usually best to wait until these have been solidly healed sufficiently long so that there is little likeli hood of recurrence of the tumor before starting the repair Reconstruction is most often done by inverting small flaps of skin from near the edges to provide the new lining, and then covering the area with a free full thickness skin graft or with a pedi cle flap from the forehead, the adjacent part of the nose or the cheek

Defects or deformities of the nostril border have been some of the most trouble some to correct If the niche is produced by the upward pull of a vertical scar, without much loss of tissue it may be possible to correct it by a small ' Z plasty on the axis of the scar and going through the full thick ness of the wall When the tissue has actu ally been lost the best correction is usually obtained by transplanting a free composite graft of the full thickness of the rim of the ear (Chap 13)

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Fig 195 Profile views of the patient shown in Figure 194 before and after reconstruction



FIG 196 (*Left*) Crumpled, collapsed nostril from almost complete loss of lining and subsequent internal scarring A fine skin hook was put on the nostril border and pulled forward and outward as the scar was dissected out from the inside of the nostril, until the nostril was completely expanded to its original shape Then a sheet of split graft was draped over the nostril and packed in with a strip of iodoform gauze, distending the nostril to oversize A small transverse scar over the middle of the nose was excised and resutured (*Right*) Appearance 2 months later with an excellent airway and no external deformity

of the forehead and then gradually narrow down by downward curvature of the upper border to a pedicle in the eyebrow region about 1½ inches in width

The flap is delayed in 2 stages, making the upper and the lower incisions and undermining between them at the first stage From 10 days to 2 weeks later, the end is cut across, and the distal inch or so of the flap may be undermined quite thinly so as to give a thin end for the nostril borders, the columella and the lining When the forehead flap is quite soft and free from any redness, edema or induration (usually about 2 weeks later), it may be swung down onto the nose Lining for the new nose must be planned carefully in advance If any remnants of the original nose are left, it may be possible to invert flaps of skin from them over the defect to provide part or all of the lining The lower part of the new nose can be lined by turning the thin distal end of the flap in under If lining cannot be procured elsewhere for the upper half of the new nose, it may be necessary to line this portion of the flap with a free full-thickness skin graft at the time that it is first raised

The position of the nostril bases and the base of the columella is carefully marked on the face, opening incisions are made to receive the flap, and the flap is brought down and sutured in place The end of the flap is folded in under on itself to make the nostrils and the columella, splitting the end into three tails if necessary Considerable shaping of the new nose can be done at this time by careful trimming and suturing, the surgeon always being careful of



FIG 197 Complete loss of nasal lining and septum in early childhood from specific infection, with resulting "sucked in" collapsed nose At the first operation an incision was made underneath the upper lip through and into the nasal cavity, and the scar was excised from the interior of the nose until the dorsum could be brought well forward and the nostrils overexpanded A dental wax mold was made of the expanded cavity wrapped in a sheet of split graft (raw side out) and inserted under the upper lip up into the nose. After the graft "took" this mold was worn for 1 month and was removed daily for cleansing At the second operation the fistula under the upper lip was closed, and a cartilage transplant was inserted into the dorsum of the nose

the blood supply clear out to the end The forehead defect is covered with fine mesh gauze and a bandage around the head The new nose is packed and further shaped with an external aluminum splint

Two or 3 weeks later the pedicle is divided at the top of the nasal defect and the remainder of it is returned to the fore head The rest of the forehead defect is covered with a thick split-skin graft, and the upper edge of the new nose is trimmed and sutured in place An L-shaped cartilage support is inserted later if necessary for support Some final trimming and shaping is almost always necessary but should be delayed until all the swelling is out of the new nose

Cheek flaps will also provide a good color



FIG 198 Profile views of the patient in Figure 197, showing the result of repair in 2 operations No flaps were used, and the total hospitalization was about 9 days

match and can be used for partial restorations They are planned with the pedicle base as close to the nose as possible, and frequently with the lower edge in the nasolabial crease In older patients with loose skin, it is often possible to close the defect by undermining, sliding the edges together and suturing However, if this distorts the lip or the eyelid, it may be necessary to close part of the defect with a supraclavicular graft These cheek flaps can be raised and transferred directly, if they are short enough and have a sufficiently wide base but in other instances should be delayed once or twice before transfer

When the forehead or t ... is not available, or the patient ... ire to use them, a flap from th ... or the upper chest may b ... are better for partial restora... om- plete reconstructions and in any event tend to be excessively white, flabby and difficult to shape accurately into a good-looking nose Shrinkage may be great, especially in arm flaps, so that they should be designed at least twice as large as the pattern of the defect, final trimming should be long delayed until one is certain that no more shrinking will occur (Fig 74)

GRAFTING INSIDE THE NOSE

Grafting inside the nose is often necessary to replace mucosal lining which has been lost by infection (Figs 196, 197 and 198) (l... or pyogenic) or for congenital vesti... ia (Fig 199). Traumatic web... airways from through-and-thr... ons may also require grafts for... Split grafts will take rou- tir... nose but do not undergo

metaplasia and remain permanently as skin They may secrete sebum and even grow hair, if thick, so that they should be cut quite thin and removed from a relatively hairless donor area. These grafts undergo much shrinkage, so that some initial over correction should be done inserting as much graft as possible. Circular scars at either the upper or the lower border of such a graft may prove to be troublesome in contracting so that it is best to avoid them whenever possible, by switching a small local flap across some part of the web and grafting the remaining raw area. Full thickness grafts can be used occasionally for very small regular areas, but most of the defects are quite irregular, after dissection, and of considerable size

After widely opening the airway by dis section (taking care to avoid exposure of any bare cartilage or bone), hemostasis is obtained by temporary packing with 1:5 000 epinephrine on gauze A fairly large thin sheet of split graft is obtained from a rela

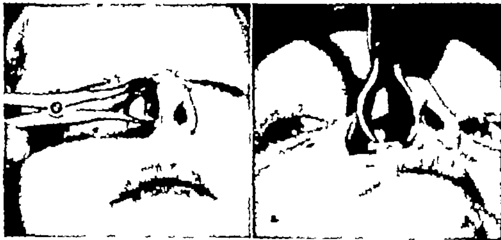


FIG 199 Congenital atresia of the nares. The left nostril was about the same as the right. A small flap was fashioned from one side of the web to line the new nasal floor The remainder of the web was cut out and a sheet of split skin graft was packed in over the strip of iodoform gauze Both nostrils were done at the same operation It is important to overdistend these nostrils initially



FIG 200 Restoration of the columella in a single operation with free composite graft from the ear (Brown J B., and Cannon, Bradford Composite free grafts of two surfaces of skin and cartilage from the ear Ann Surg 124 1106)

tively hairless donor area and is draped over the nostril opening A strip of iodoform gauze is packed through the center of the graft back into the airway, carrying the graft with it, past the raw area The packing is continued until the nostril and the airway are overdistended Counterpressure is obtained by means of an external aluminum nasal splint The packing is removed on the 4th day, the excess graft is excised, and then repacking is done daily, with cleansing and application of some mild antiseptic, for 2 or 3 weeks

Columellar losses may be the most difficult of all and require ingenuity for their repair Local shifting of tissues and free composite grafts from the ear are used whenever possible (Fig 200) At times, a flap may be advanced from the upper lip into the columella, as in secondary double cleft-lip repairs When the entire columella is missing, it may be necessary to bring in a distant flap from the arm or elsewhere

Nostril floor defects are usually filled in with a tiny flap from just outside the base of the nostril The pedicle is in the upper lip, and the flap is switched from just outside the nostril to just inside it

25

Repairs of the Ears

ACQUIRED DEFECTS

Losses of the external ear are numerous and often complicate other serious defects so that plans for rapid and simple restoration are important without the use of massive distant flaps or great numbers of operations (Figs 201 to 209) The losses result mostly from burns gunshot wounds traffic accidents and freezing Congenital absence and loss from neoplasms account for a relatively small but important number

Whatever plan of repair is used it is best as a preliminary measure to replace any sizable amounts of scar tissue in front behind or above the ear remnant with soft and pliable free skin grafts Since the skin just above and behind the ear remnant probably will end up on the front of the new ear rim one can consider using postauricular skin graft from the other ear or supraclavicular skin graft for this area. If a large amount of skin replacement is necessary split skin from the lower anterior chest is used

For replacement of only the rim and a small amount of adjacent tissue no cartilage transplantation may be necessary The edge of the ear stump is freshened and implanted into the skin (or skin graft) behind and above it and allowed to heal in for 3 or 4 weeks The outline of the new ear is then drawn in with methylene blue and a further outline is drawn outside of this to include enough skin to make a rolled helix and to surface the back of the repaired portion Then an incision is made outside this last line and the skin flap and ear stump are elevated from the head the flap is rolled into a helix and a new back, and the bare place on the head is covered with a fresh split skin graft (Figs 208, 209 and 210)

If a larger segment of ear is missing so that a cartilage transplant will be necessary to replace part of the framework the preliminary work and the first stage are also done as above When union is firm (2 or 3 weeks) an adequate piece of costal cartilage is put in under the scalp flap in the desired shape In another 3 or 4 weeks when there is no swelling the flap and the cartilage are dissected free of the skull so as to leave soft tissue attached to the undersurface of the cartilage and to the skull This procedure requires accurate careful dissection The resultant double raw surface is grafted with a single large thick split graft Later adjustment may be necessary If there is not adequate size or the patient requests it a small tubed flap from the immediate neck region can be added for the helix however this is seldom requested

With this simple plan, losses of the helix and the pinna can be repaired in 2 operations and total reconstructions of both ears have been done in as little as 3 operations (Figs 204-209)

In making an ear, skin in front and behind is needed with adequate support (or armature) in between. The scalp skin that was behind the ear is brought to the front surface of the ear, cartilage (preserved or fresh) forms the support, and a free graft goes in behind It is recognized that a completely normal total ear cannot be made

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There is no tissue available to make it with if it could be done Although fresh (or preserved) ear cartilage may be used, or chips of costal cartilage may be molded into the exact shape, the skin available usually will not fit into the various recesses of the concha, the triangular space and the curves of the helix to bring these variations of the cartilage into prominence For these reasons, the restorations are recognized as substitutions, and size, general shape and direction are concentrated on in total restorations, but a general outline and prominence may at least fail to attract notice Many friends and surgeons have talked to the patient in Figure 204 without noticing that both external ears have been totally reconstructed

Prosthetic ears of latex or soft plastic are used according to patients' wishes They look like normal ears at a slight distance but have the trouble of falling off and require more care than most patients want to

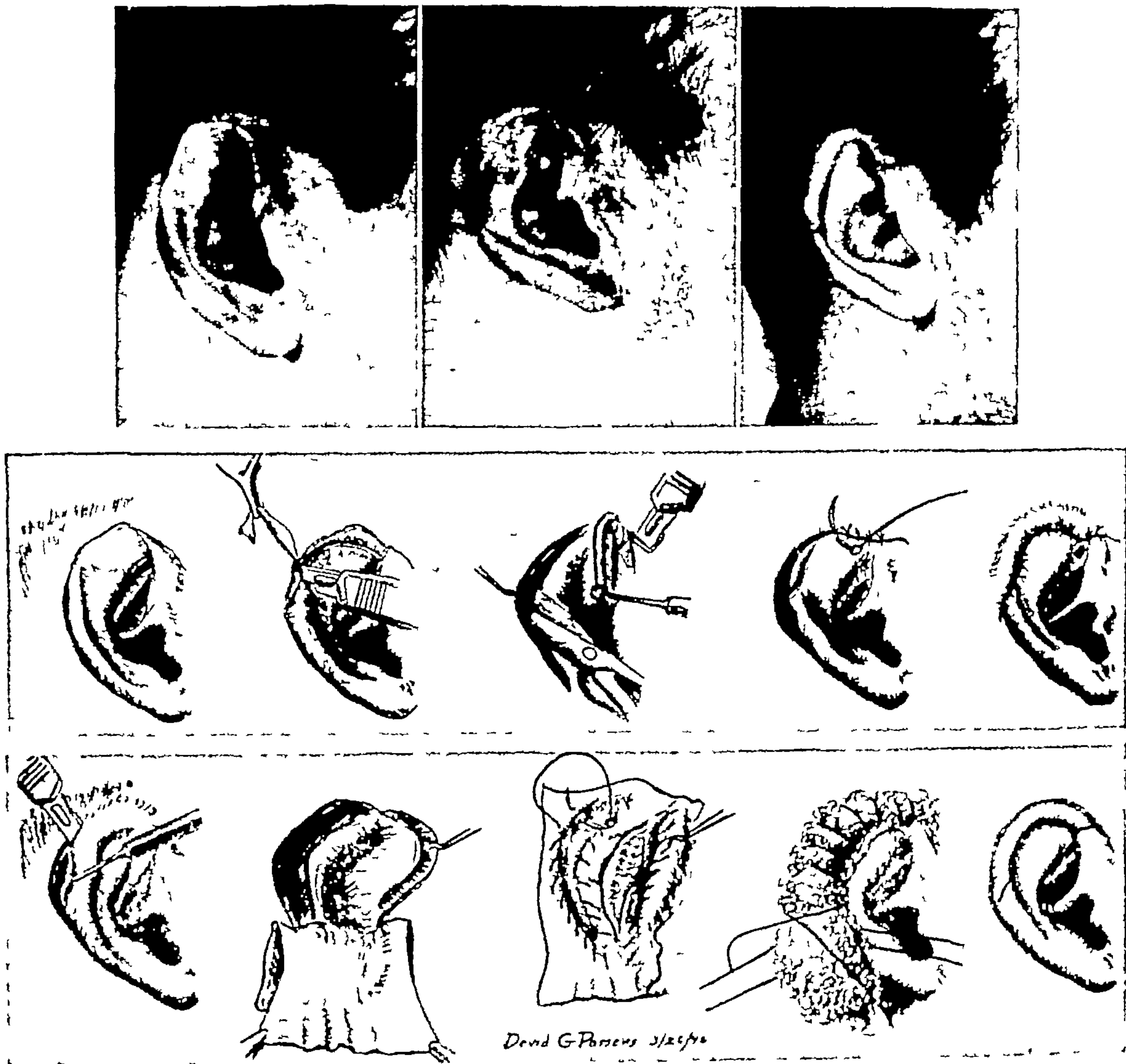


FIG 201. Rim restoration without cartilage implantation (*Top*) Restoration of the crus of the helix and the helix with local flap and graft in two operations Middle view shows ear implanted in the scalp (*Center and bottom*) Operative steps (1) Edge opened (2) Scalp pocket prepared. (3 and 4) Edge buried in scalp to complete first operation Second operation· the ear is cut loose from the scalp, and a split skin graft is stented behind it (Brown, J B, et al · Surgical substitutions for losses of external ear, Surg, Gynec & Obst 84 192)



Fig 202 Ear rim reconstruction without cartilage transplant Loss from hemangioma with much surrounding scarring First operation split graft applied in front above and behind ear Second operation some months later the top of the ear was denuded and buried in the skin graft above Third operation the top of the ear with attached flap of skin was taken loose from the scalp, and the flap was rolled around to make a new helix A scalp defect was grafted

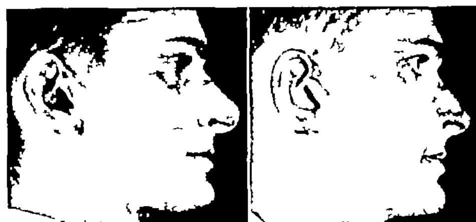


Fig 203 Total ear rim reconstruction *without cartilage transplant* in same method as used in Figure 202 The nose also resurfaced with skin graft, which is shown here at an early pink stage but later it bleached out The ear rim result was much superior to the use of a blobby little flap from the neck, with visible neck scarring etc.



Fig 204 Major ear repairs with cartilage transplantation Almost total loss of both ears in one patient from freezing injury Both were repaired in 3 operations by burying ear edges in skin behind transplanting carved rib cartilage under the skin, dissecting the new ear loose and putting a split-skin graft behind it







FIG 205 (*Top*) Gunshot loss with occlusion of canal that was opened with flaps of local tissue Reconstruction done with neck flap brought up in stages and with preserved cartilage support (*Bottom*) Loss of about one third of bulk from fire Reconstruction with local flap preserved cartilage and split graft

FIGURE 206

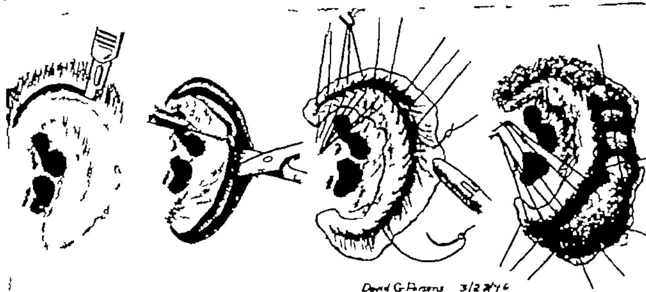


FIG 207 The drawings of Figures 206 and 207 show operative steps in total reconstruction of ear in 3 operations At the first operation, the edge is freshened and buried in scalp pocket behind Second operation 3 weeks later an opening is made well above, and a complete tunnel is made in the area. The curved portion of a costal cartilage is carved to simulate the normal contour and is buried in the tunnel Third operation the new ear is carefully dissected forward the surgeon being sure to leave viable soft tissue both on the back surface of the cartilage and the outer surface of the skull. The double defect is covered with a split skin graft. (Brown J B, *et al* Surgical substitutions for ear losses, Surg Gynec & Obst. 84 192)

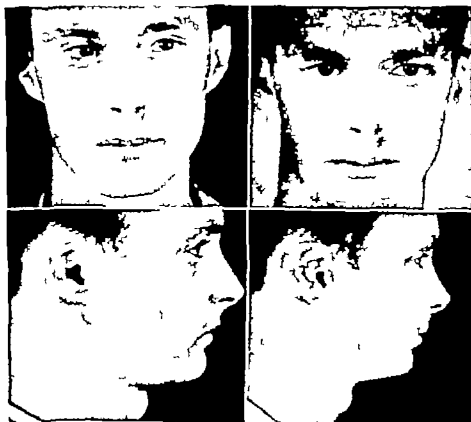


FIG 208 Reconstruction of the upper ear with cartilage transplant in 3 operations, for traumatic loss. (1) The top of the ear remnant was denuded and imbedded in a slash pocket of skin above (2) A rib cartilage transplant was carved into shape and inserted (3) The ear top was taken loose from the head and split-grafted behind This method leaves almost no visible surrounding scars. The patient had a strabismus operation done between the ear operations and other ear was also set back a little



FIG 209 Nearly total loss of ear from dogbite, repaired in 3 operations, as described in Figure 208 Preserved cartilage was used, which later underwent some absorption, with need of autogenous replacement The normal ear was set back some

give (Their routine use would be acceptable to most surgeons) What the patient wants is the deciding point

One deformity that occasionally occurs is loss of skin without crumpling of the cartilage, but with the ear healed clear back against the skull so as to be hardly discernible as an ear Sometimes much can be gained here by simply freeing the cartilage from the scalp and grafting behind it and on the scalp The result will not be perfect but may be better than the usual total reconstruction

Small defects about the rim or the upper portion of the ear can be filled in occasionally with a composite graft from the other ear Thus a large curled-over helix on one ear can be converted into a small but natural-appearing curved helix on both ears

Congenital absence of the ear may present a more difficult problem than traumatic loss The vestigial remnants that are present may be too far forward, either too high or too low, and may be associated with loss of the middle ear, loss of the internal ear, loss of the 8th nerve, weakness or absence of some branches of the 7th nerve, and a short mandible on the affected side The crumpled remnants of cartilage can no more be straightened out than could a clock spring The first operation usually consists of excising this crumpled cartilage, smoothing out the skin, shifting the lobe to the proper location and making certain that

Fig 210 Congenital absence of the ear Reconstruction by (1) excision of some cartilage remnants and repositioning of lobe (2) implantation of carved rib cartilage framework, (3) detaching the ear from the head swinging the ear forward and skin grafting behind it. The normal ear was set back. While leaving much to be desired, the results by this method are as good as or better than any other method, and a lifelong series of operations is not required

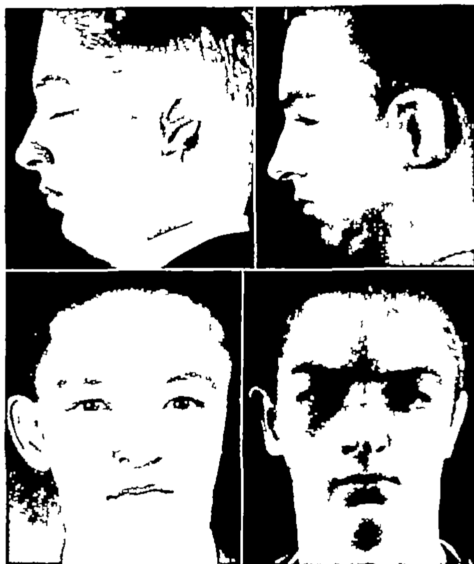




Fig. 211 Congenital absence of most of the ear Repaired in a few operations by the method described in Figure 210



FIG 212 Congenital absence of the ear The hairline came down too low to start out the usual repair, so a segment of adjacent hair-bearing skin was replaced by a supraclavicular free skin graft, as a preliminary operation Then reconstruction was carried out, as described in Figure 210

enough smooth skin is present in the correct location to make the anterior surface of the new ear Frequently, the hairline is too low, so that it may be necessary to excise some scalp above and replace it with a free graft from behind the opposite ear (or from the clavicular area) The second operation consists of putting a carved sheet of costal cartilage for framework and usually is done at 4 or 5 years of age, or whenever enough growth has taken place so that a framework for an ear 55 to 60 mm in length can be inserted (the ear does most of its growing during the first 4 or 5 years of life) The third operation is hinging the new ear out from the skull, and skin grafting behind it Later work may consist of trimming and adjustments, adding a helix flap, building out the jaw line with cartilage, or whatever seems necessary in the particular patient (Figs 210, 211 and 212)

If a canal is put in, it is usually for appearance rather than for hearing (in these congenital absences) and can be done at the first operation Many involved technics requiring a myriad of operations have been described, but the results seldom justify the means.

Congenital absence of the external auditory canal be treated, in some instances, by creating a canal by dissection and lining it with a split skin graft Preliminary roentgen studies are made to determine the presence of a bony canal, as well as examinations by an otologist to indicate the probability of a useful hearing mechanism on that side In general, children with a fairly large and well-formed ear remnant are apt to have a good bony canal lined by a blind epithelial pocket or cyst and present the possibility of reconstruction of a good auditory canal Those with only small skin tags or cartilage remnants are apt to have no bony canal or one that is too small to use

An incision is made behind the external ear over the anterior edge of the mastoid process and extending downward to within about 1 cm of the mastoid tip The ear is reflected forward, and the dissection is carried down onto the bare bone of the anterior edge of the mastoid and then upward to its superior extremity Just anterior to this, and a little deeper, the canal is encountered. At times, it will be lined with definite epithelium and may even contain cerumen, but in other instances the bony canal will be filled with areolar tissue which must be removed. (Care must be used in




Fig 213 Congenital absence of the auditory canal Roentgenograms showed a bony canal and hearing tests indicated auditory mechanism on this side. An incision was made behind the ear down to the anterior surface of the mastoid, then upward and forward to enter the bony canal The membrane in the bony canal was opened, exposing an epithelial pocket containing cerumen A small skin flap was elevated on the anterior surface of the pinna and dissection was carried through the ear The incision behind the ear was closed The flap was turned down into the bony canal to line the floor The remainder of new canal was lined by a split graft inserted over a dental wax mold (The little flap avoids the circular scar which would result if a graft alone were used)

this dissection to avoid injuring the facial nerve)

A small skin flap is then fashioned on the anterior surface of the ear long enough to reach the bottom of the bony canal or the epithelium in it and wide enough to line one side of the new canal The base (or pedicle) of this flap is usually in the antitragal region and the flap is removed from over the new orifice and as far forward as the region between the tragus and the crus of the helix. The distal end of the flap is quite thin but it may be thicker back at the pedicle. The flap is turned down into the canal to line the postero-inferior segment and if possible is fastened with 1 or 2 sutures at the end The incision behind the ear is closed, and the remainder of the canal is lined with a thin split skin graft put in anteriorly over a dental wax mold The mold is removed in 5 days any excess graft is excised and the mold is replaced. The mold is removed every 2 or 3 days for cleaning and is replaced until it has been in place for 1 month. The small flap lining one side of the canal tends to prevent circular constriction of the graft and to ensure a permanent patent canal (Fig 213)



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26

Repairs of the Neck

FREE SKIN-GRAFT REPAIRS

On necks, it is thought that free skin grafts will effect the best profile whenever they can be applied (Figs 214 to 219) They may not be as generally smooth as flaps on the surface, but flaps are apt to be heavy and expressionless-looking and, worst of all, may result in a straight line profile without any definitive angle between the neck and the jaw (Fig 87) The growth of free grafts over such a movable object as the larynx is difficult, but this type of repair can be done successfully even though statements have been made that it is impossible

If the repair is done before the area is healed, split grafts are always used (Fig 214), and if there is a dirty sinus present, it is opened and the whole area is converted into an open wound As stated before, any unhealed surface is considered as dirty, and full-thickness grafts are not risked in these areas When completely contracted necks are dissected open, there may be such a huge defect that split grafts are the only available means of repair (Fig 215)

Deformity may be so great that the patient cannot look the world in the face, and a normal social and economic status is impossible In children, a wide-open bite of the jaw may develop because of the pull of the scar on the chin (Figs 215 and 216) In this situation, the first premise of treatment is to open and cover the neck so that the head may be held up and the jaw returned to its normal occlusion It is almost





FIG 214 (*Left*) Complete loss of skin of neck and part of face, with a deep dirty sinus in the scar The jaw was twisted down into an open bite, the molar teeth being together This was restored in 2 thick split and 1 full-thickness graft operations (*Right*) Result has persisted through a 9-year growing period (Clinics 1 25)






A B






C D

Fig 215 (A) Severe neck contracture with wide-open bite from traction on jaw by scars. (B) Pressure dressing after first operation (C) First dressing after split graft operation the marine sponges have made an accurate cast of the area. (D) Final result after a second operation in which a full thickness graft was inserted across the front of the neck The teeth have returned to occlusion without the use of any appliances. The helix of the right ear has been restored with a small direct flap from just behind it (Surg Gynec. & Obst 60 379)



FIG 220 (*Left*) Heavy, thick, wobbly flap repair of the neck, put on in a long series of operations elsewhere, to extreme dissatisfaction of the patient. Mouth closing requires conscious effort, because of the weight of the underlying curtain of inert tissue, this even pulls the angles of the mouth down (*Right*) The flap was removed and replaced with thin, flexible, free grafts, which look and feel better and also move better

front and both sides of the neck and behind and over both ears With the head extended, this is bound on with a gauze roll wrapped continuously in 3 successive turns, (1) around the neck, (2) around the head at the forehead level, and (3) a vertical loop passing under the chin, over the top of the head and in front of both ears Outside of this, a gauze bandage is wrapped tightly and continuously in the same 3 successive turns, and this is bound on with a roll of 1-inch adhesive The bottom of the neck dressing is fastened to the chest with large straps of 2-inch adhesive The completed dressing should exert uniform firm pressure—upward on the upper part of the neck between the two horizontal sides of the mandible, backward on the front of the neck, and medially on the two sides If enough waste padding is used over the larynx and the trachea, and if care is taken in the application, this can be done without interfering with the airway The dressing is applied with the head and the face straight and slightly extended. and if firmly secured to the head and the body, will immobilize the neck sufficiently so that plaster cast fixation is neither desirable nor necessary

"Z" PLASTIES ON THE NECK

The "Z" plasty, or rotation and interdigitation of triangular flaps from either side of the wound, does not create any more skin but simply rotates the axis of tension through 90° (Fig 107) Therefore, it is useful only when there is looseness horizontally and just slight tightness vertically Some loose vertical webs, and some vertical incisional scars which are pulled out into a web can be repaired best in this manner Congenital lateral webs of the neck can also be improved by this procedure, though it does not obviate the deformity caused by the short, wide, heavy musculature that is often associated with this condition

"Z" plasty is not indicated for the usual burn contractures of the neck, in which there is gross loss of skin with extreme tightness in every direction



FIG 221 (*Left*) Flap repair put on burned neck in over 100 operations elsewhere, to extreme dissatisfaction of the patient. She could not even close her lips due to the heaviness of the flap repair and did not desire many more operations (*Right*) Result of cutting across the flap restoring the neck angle, and inserting a free graft from ear to ear Now she can close her mouth easily See also Figure 222

"Z" plasties with scar flaps are apt to end in failure in any situation, and "Z" plasties of skin graft flaps have an uncertain prognosis.

PEDICLE FLAP REPAIRS OF THE NECK

Pedicle flaps are rarely indicated for open burns or burn contractures of the neck. One might conceive of a case with marked keloid tendency and tremendous deep scarring where a flap might be indicated, but if used, it is apt to end up as a flabby inert mass hanging in a straight line from the chin to the sternum Many such patients have been seen who have had these



FIG 222 Profile view of patient in Figure 221, before and after cutting across the flap establishing the neck angle and inserting a free graft to free the lower jaw from the neck and the body These heavy curtain flap repairs of the neck are rather typical of the many that have been seen for secondary correction (The final photo in this patient is less than 4 months after operation, so the border scars around the graft have not settled down yet.)

repairs done elsewhere (Figs 220, 221 and 222), and in most instances the remedy is to remove the entire flap and apply free skin grafts directly on the underlying neck musculature In some instances, the flap has been cut across horizontally, the edges spread, and a skin graft inserted to make an angle between the neck and the jaw

Pedicle flaps are indicated for some deep defects resulting from radiation burns or the removal of tumors A permanent pedicle blood-carrying flap (cf Chaps 12 and 32) is usually the method of choice and sometimes can be obtained from elsewhere on the neck or from the adjacent upper chest (Fig 94)

Back flaps, percentage-wise, yield so few good results on the neck that their consideration might be omitted

Arm flaps can be used for small repairs, but in such instances it is often possible and preferable to use a permanent pedicle blood-carrying flap

Jump flaps can be brought up on the wrist or the forearm from the abdomen, preferably as open flaps rather than tubed ones Again, however, there is the distressing tendency for the flap to hang as a curtain from the chin to the sternum, and for the very weight of it to pull down on the lower lip and tend to keep the mouth open

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Repairs of the Scalp

OPEN BURNS

For the usual burn of the scalp there is frequently a long period of procrastination in repairing the defect with a graft This is partly due to the extreme depth of the hair follicles so that hairs may grow up through a granulating surface, and the follicles epi thelium ultimately effect healing When this is going to happen there should be some evidence of it within 4 weeks and if there is not, grafting should be done Healing with scar epithelium from the edges is extremely slow and there is almost certain to be re peated breakdown and ulceration of the new surface, much to the patient's final disgust.

Such burns may be from heat where the clothing or the hair has been on fire or flash burns from explosions hot liquids or tar etc. One type seen occasionally is fol lowing an automobile accident in which the patient s head has been pinioned under the car against a hot exhaust pipe with the



FIG 223 (*Left*) Large painful wound from full thickness loss that probably would never heal (*Center*) Complete healing with a thick split graft. One operation (*Right*) Per sistence of function after 6 years. (Clin ics 1 25)



FIG. 224 (*Left*) Burn of scalp from beauty-parlor combs In this region scar epithelium is slow to form and usually gives an unsatisfac tory bearing surface with marked tend ency to repeated ul ceration (*Right*) Restoration done in one operation with a single split graft (Surg Gynec & Obst. 60 379)

motor still running Other deep lesions may be seen following electrical burns, chemical burns, meningitis sloughs, sloughs from sensitivity to sulfa drugs or other allergies, etc

Once it becomes evident that grafting will be necessary, preparatory dressings and treatment should be carried forward If the area is small, shaving for an inch or so around may suffice, but if the area is fairly large it is usually necessary to shave off all remaining hair and keep it off Daily soap and water cleansing and wet dressings may hasten satisfactory preparation of the granulations It is especially important that the surrounding area be kept clean at all times

Grafting of this area is simple, and practically all repairs can be done with thick split grafts Of course, the grafted areas will be bald, but the remaining hair usually can be arranged to cover them (Figs 223 and 224)

For small areas, "tie-over" dressings may be used locally, but large grafts are simply sutured in place around the edges The external dressing is always a little difficult Surgical waste is used for padding, and a craniotomy type of gauze roll and bandage dressing may be used, with or without the addition of turns under the chin If the entire head has been shaved, multiple strips of Elastoplast can be anchored back and forth across the graft, under elastic tension, and their ends fastened down with cross-strips of ordinary adhesive tape

THE PROBLEM OF DEAD EXPOSED SKULL

If the periosteum has been lost, the problem is greatly complicated because free skin grafts will not grow on bare cortical bone, and if such bone is left bare and exposed for a day or two, the outer table becomes dead and will not accept a flap

Following excision of scalp tumors, immediate split grafts can be used if a periosteal bed remains If bare bone is exposed, a direct local flap should be switched over it immediately, and the donor area covered with a split graft

Following burns of any type, the appearance of exposed skull calls for gentle treatment and wet dressings as long as there is any periosteum or soft tissue of any kind overlying it that may be viable and give rise to granulations Once the bone is completely bare, and clicks when lightly touched with a metal instrument, the problem becomes one of getting rid of dead bone satisfactorily (Figs 31 and 267)

It is not always possible to determine whether the inner table is alive, or the entire thickness of the calvarium is dead The history of the length and the intensity of the heat or other injurious agent may be helpful In general, in large areas of exposed calvarium, both tables are apt to be dead, whereas in small areas, more often only the outer table is necrotic In case of doubt, several shallow drill holes can be put just through the outer table with neurosurgical perforators and burrs, if it is thought safe to do so; and one can await the appearance of granulations from between the tables If these appear, usually the intervening portions of outer table can be pried off gently, and then the whole wound will granulate in a few days

If it seems probable that both tables are dead, it is often best to prepare a delayed local permanent pedicle blood-carrying flap in advance of the bone removal operation, provided that the area is small enough that such a covering flap is possible The flap may be based on either temporal artery, either occipital artery, or any combination of them Once the flap is ready, the area of dead bone may be taken out by the usual neurosurgical technics and the edges rongeured back to live bleeding bone all around, and the flap then swung in place If such a flap cannot be prepared, it may be possible to put split skin grafts on the dura or the underlying soft tissue (we have even seen split grafts grow on a fungating brain tumor), and subsequently replace them with a flap from someplace, even a jump flap carried on the wrist, if necessary. However, it is better to use local flaps wherever pos-

sible, even including forehead flaps adja cent scalp flaps, or neck flaps based behind the ear

Split skin grafts applied over periosteum or over granulations covering the inner table will frequently provide satisfactory permanent resurfacing If not they can be replaced later with a flap Split graft applied over dura or soft tissues in the ab sence of bone usually should be replaced with a flap Still later support can be put in as a bone graft, or inert implant as preferred

Neurosurgical consultation and help is of the greatest assistance in all of these diffi cult problems

OLD BURN CONTRACTURES AND MARJOLIN ULCERS

Old granulating scalp wounds may heal eventually over a long period of time but the resultant scar epithelium is unstable and permanently troublesome The skull is a rigid box and noncollapsible so that there is tension to begin with and recurring ten sion with repeated breakdown and ulcera tion of the scar surface.

Some patients are seen with extensive tight scarring of the scalp and the forehead who have the eyebrows pulled up in a per manent attitude of surprise and cannot close their eyes because of the tension from above In these patients relaxation of the brows and normal closure of the eyes for the first time in many years usually can be effected in one operation by removal of the surface scar dissection of the eyelids and the brows downward and covering the defect with a large split graft (Fig 327)

Other patients are seen with extensive tight scarring of the scalp and repeated breakdown until squamous carcinoma de velops This is one of the frequent sites of Marjolin ulcers The best treatment is pre vention excision of the scar pushing back the normal skin edges and resurfacing with split grafts before carcinoma develops However if carcinoma has developed it may be limited to the soft tissues for a time, during which it can be resected and the defect covered with a split graft (Fig 225) or a local flap If the carcinoma be comes fixed to the skull then the under lying bone must be removed en bloc with it and the resulting defect covered with a flap



FIG 225 Tight burn scar of scalp (*top*) of 40 years duration Repeated breakdowns with carcinoma (Marjolin s ulcer) are now present but slightly mov able over skull (*Bottom*) Result after wide excision and split grafting The split graft is soft, elastic, and moves freely on the calvarium

AVULSION OF THE SCALP

Avulsion of the scalp is becoming an in creasingly common industrial injury in women due to the fact that long hair is easily caught in rotating machinery (Fig 226) If the flap is still attached to the head the edges are examined for bleeding and



FIG 226 Total avulsion of scalp, forehead and eyebrows (*left*) by industrial machinery (*Center*) Result after primary coverage with split-skin grafts (*Right*) Result after fitting of wig, and soon after free eyebrow grafts had been transferred from a little remaining hair on the nape of the neck

other evidences of viability, it may be trimmed back as far as necessary to get bleeding edges, and then the viable portion sutured back in place If it is completely torn off, it is better to resurface the head immediately with thick split-skin grafts from the thighs or elsewhere There are intermittent reports of shaving of the removed scalp, defatting the undersurface, and replacement as a free graft, but the take is usually spotty, and the hair growth is so poor that a wig is necessary anyway

CONGENITAL ABSENCE OF SCALP AND SKULL

Children are seen fairly often with small congenital bald patches on the top of the head, sometimes covered with only a glazy scar epithelium No treatment may be required, or it may be worthwhile to try multiple excisions and suturing

Rarely, a child may be born with absence of a large area of scalp and skull over most of the top of the head Such a patient is shown in Figure 227, with even dura absent, and a large area of pia arachnoid and brain exposed This was covered permanently in one operation at the age of 2 days, raising a large local permanent pedicle blood-carrying flap, suturing it over the defect, and split grafting the donor area To help in outlining and planning the flap, the branches of the temporal and the occipital arteries were carefully palpated with the bare finger and outlined on the surface in methylene blue After this, it was possible to devise a single large flap based on the temporal artery and its various branches that would swing over the defect and cover it This patient is now 4 years old and seems to be well in every way, with no neurologic deficit apparent after repeated neurologic examinations

OTHER LESIONS AND REPAIRS

Radiation burns may result from treatment of ringworm of the scalp, or other causes Some are so extensive as to require excision of the skin and resurfacing with split grafts In others, there may be even death of bone, necessitating removal of the bone and a flap repair, as outlined earlier in this chapter

Electrical burns may be deep with necro-



FIG 227 Congenital absence of scalp and skull (*Top, left*) Appearance at age of 24 hours with pia-arachnoid exposed. This was covered immediately by a direct long permanent pedicle blood-carrying flap based on the temporal artery, and extending back over the occiput. The flap donor area was split grafted at the same time (*Top right and bottom*) Result shown at age of 18 months The child is now 4 years old and is developing normally in every way Probably will have a bone graft or a metal plate put in later One operation Two weeks of hospitalization

sis of the underlying skull The repair is as outlined earlier in this chapter, and in the captions of Figure 267

Tumors may require resection of soft tissues, with skin grafting, or soft tissues and bone, with repair by a flap, as described earlier in this chapter (also cf Chap 29)

SHIFTING FLAPS TO RESTORE THE HAIRLINE

Bald split-grafted areas within the scalp usually can be covered satisfactorily by letting the surrounding hair grow long and combing it over the spot

However, a bald split-grafted area at the edge of the scalp or in the hairline creates an unsightly deformity, particularly in men which cannot be covered satisfactorily with adjacent hair In this instance, it is usually best to shift in a flap of the normal adjacent scalp to make a new hairline, the donor area of the flap is split-grafted, of course, but is well within the scalp where it can be covered by adjacent hair (Fig 228)



FIG 228 Switching of flap from back of scalp down to cover the bald spot in the temple (result of trauma) and create a hairline The donor area has been covered with a split graft, which is also bald, but this area is easily covered by combing hair over it

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Postmortem Homografts and a Skin Bank

Postmortem homografts may be obtained from patients soon after death and used the same as fresh homografts This procedure makes more readily available a method of supplying a "biologic dressing" for temporary sealing of large burn wounds or extensive skin losses and may be a lifesaving measure (Plate 2 Figs. 237 and 238) It has been used routinely on our service for several years and there seems to be no reason to go back to the old procedure of obtaining numerous smaller homografts from a series of anesthetized live patients in this work

The postmortem grafts are living and will proliferate new epithelium from their edges in 7 to 10 days when obtained and used as recommended in this chapter This is due to the fact that there is a differential time lag between systemic death (cessation of breathing and heartbeat) and cellular death in the various tissues in the cells of the skin this may amount to several hours or much longer if refrigeration is employed

The living postmortem skin grafts described here should not be confused with lyophilized skin or other dead grafts or inert substances. Each has its own properties and uses

The living postmortem homografts "take" in the same manner as fresh autografts are invaded by the host's blood vessels and connective tissue sustained by his circulation become pink, grow and in general become part of his body until he develops an allergic reaction to them and sloughs them off some weeks later During this period, they seal his body fluids in and act as a protective mechanism, apparently almost as well as his own intact skin Fresh postmortem homografts persist as long and have the same properties as fresh ones from live donors, provided that they are obtained with aseptic technic from suitable donors within the first hour or two after systemic death

Desiccated, frozen, lyophilized, or other dead skin homografts may adhere to a raw surface for periods of 10 to 30 days and provide the next best variety of sealing for extensive open wounds in debilitated patients. They may be infiltrated by the host's connective tissue in the same manner that a plastic sponge or other inert material may be infiltrated but there is lack of agreement among investigators as to the establishment of circulation in them, or the nature of it and they definitely do not grow They do have the advantage that they can be stored for longer periods of time

Living postmortem homografts can be preserved in a skin bank for a few weeks with a progressive loss in the percentage of "takes" and in the duration of their persistence.

Synthetic or other natural materials



FIG 229 (*Top*) Very dirty wound from complete, circular full-thickness loss of skin On one occasion, the patient had been taken from the hospital by her parents because of extremely bad reaction to treatment (*Bottom*) Full take of homografts from mother, shown at first dressing on 4th postoperative day (Surgery 1.558) This was done in 1927, and postmortem homografts would be used for this purpose now

have been proposed and investigated for sealing large burn wounds, and if a satisfactory one could be found that would persist for several weeks, homografts in any form would become obsolete

The use of postmortem homografts provides large amounts of grafts from a single source without disfiguring the donor patient, and it avoids discomfort and the time loss to comparable live donors, as well as attendant wound care, pain and occasional surface scarring There can be large savings of operative time, expense, physical examinations, anesthetics and postoperative care In one Eastern newspaper recently, there was an article about the use of 100 live homograft donors to cover and recover a single burned patient, this sort of thing can be avoided and carried out to better advantage for the patient by the systematic use of postmortem skin homografts and the maintenance of a skin bank

USE AS A LIFESAVING MEASURE

Homografts of skin are lifesaving in many instances They have been used clinically for this purpose in a large number of patients on our service for over 20 years and have



FIG 230 (Same patient as in Figure 229) (*Left top*) Another view of homografts. These persisted for only 2⅓ weeks, but the wound was much cleaner the patient more tractable, and healing had begun (*Left, bottom*) Four days after second operation showing full take of autografts Also shows small experimental homograft that had been stored in icebox for 6 weeks with apparent partial take, but it was all gone in 10 days (*Right*) Final result with split autografts also showing well healed donor site on opposite leg (Internal Abstr Surg 67 105)



FIG 231 (Same patient as in Figures 229, 230) Lateral aspect of thigh 4 days after operation showing full take of fresh autografts on lower half No take of upper half where homografts that had been stored in the patient's serum for 3 weeks were used

been reported many times Their use has been so successful and so routine as to constitute an essential part of the work

Postmortem homografts (in good living condition) "take" as well as autografts and "seal" raw wounds equally well. They proliferate new epithelium from their edges which is grossly visible in 7 to 10 days and will bridge small gaps between them or between them and adjoining normal skin or autografts

Homografts of skin probably never persist permanently except in the case of identical twins (Fig 239) but may survive

from 3 to 10 weeks or longer During this period, they survive as living skin and may even grow

After the shock phase is over, the ill effects in a large chronic burn are due to (1) the presence of dead tissue, (2) infection, (3) leakage of life fluids from the body, and (4) pain from exposed nerve endings The dead tissue must be removed before the skin homografts can be applied, and the growing homografts are a specific, if temporary, cure for the other effects They grant the patient a reprieve from his exhausting illness or break it up into stages and give him a chance to build up and marshal his resources to win over the disaster

Perhaps the most dramatic effects appear in some emaciated, moribund, patients who are first seen some weeks or months after sustaining a large deep burn These patients may have a high, persistent or swinging, fever in spite of the use of all known antibiotics They may have anorexia, vomiting, diarrhea, evidences of impaired kidney function, bouts of pneumonia, a clouded sensorium, and a morale completely broken by long-continued pain Intravenous administration of electrolytes, fluids and blood seems like putting them into a sieve—as blood levels may fall even lower after such administrations Some of these patients will die despite all efforts, but some can be saved by massive homografting of split skin A few days after homografting the temperature may come down to a low-grade fever or even to normal, they may start eating well or may be able to tolerate continuous gastric drip through a small-bore plastic stomach tube, narcotics may be reduced, the sensorium may clear, and morale improve with the lessening of pain It becomes possible for them to move around in bed, be up in a wheelchair, or even to get up and walk around in their homografts, in some instances Intravenous administration of electrolytes and blood, after an initial lag, brings up the blood levels They may gain weight and present an entirely different picture in 2 or 3 weeks, at which time autografting may be begun

Homografts are also of value in the patient with a recent large burn Surgical débridement can be done in stages (e g , one extremity, of half of an extremity at a time) and after 2 or 3 days of wet dressings, homografts wrapped in place over these clean areas Simultaneous autografting can be done as tolerated, doing high priority areas such as the face and the hands first, followed by the neck, the genitalia, and areas around joints Homografts are then replaced, as they disintegrate, by autografts, so that all of the final coverage is with autografts

Many patients with huge raw areas will make no attempt to grow new epithelium, even though the wounds are kept quite clean and free from gross infection The wound margins may remain entirely stationary for weeks, and autografts may take quite well but not proliferate even a single millimeter In such instances, coverage of most of the remaining raw areas with homografts may result in sudden and rapid growth of autoepithelium, in a week or 10 days This epithelium may even replace all of the homografts in a fairly short time It is scar healing, of course, and may have to be replaced later with autografts, but will persist for permanent coverage in some flat areas

Homografts are also of value in some patients who have smaller old burns involving only one extremity, or even less, but are completely demoralized by long-continued pain Some of these patients have little or no desire to live, are addicted to narcotics, refuse to eat or co-operate in any manner, are miserable themselves and make everyone around them miserable Often, the best solution is to clean the wounds thoroughly once or twice under general anesthesia and then to wrap them completely in homografts After the homografts take, the pain will be gone, and gradual withdrawal from narcotics can be instituted Once the patient realizes that he can be cured and that his

pain is gone, he usually becomes more tractable, so that later replacement with autografts is feasible

Homografts are also of use in large burns with limited donor areas to keep the patient in reasonably good condition until final coverage with autografts can be attained in several stages over several months time Some patients will only have one or two small decent donor areas, and it may be necessary to cut four or five "crops of autografts from the same donor area In this instance it is necessary to cut the autografts thin dress the donor areas carefully and to wait about 3 weeks between cutting crops "

Homografts should not be used in recently burned patients in relatively good condition whose burns are small or medium in extent who can be covered directly with autografts in one or two operations In such instances homografts create a delay rather than a respite, and the primary object in all instances is to get final permanent healing and functioning at the earliest possible moment

Successive "crops" of homografts can be used from different donors in patients with unusually large burns and tiny donor areas so that final coverage takes several months. As many as 5 "crops" of homografts have been used on one patient When one crop is rather "moth-eaten" and loose it is not necessary to wait for final and complete disintegration usually the remnants can be scrubbed off in one or two sessions and then another crop of homografts applied

Fetal membranes zoografts blood clots and various other "biologic dressings" have been reported sporadically with apparent success from many different centers for a long time but seem to drop quickly into disuse So far as is known split skin homografts are the only substance that has been used with routine success for temporary sealing of large burn wounds in a great number of patients over a long period of time

RELATION TO BLOOD TYPES

Blood grouping has little if any relationship to the take of homografts In following one series of homografts from 26 donors applied simultaneously to one patient (Fig 232) no relation was found either to the percentage of take or to the length of persistence This series was typed by Dr Francis E Holfort down to even the M and the N groups The first dissolution appeared in 3 weeks, and all the grafts were gone in 10 weeks, with an average persistence of from 5 to 6 weeks Similar observations have been carried out on other patients.

THE TECHNIC OF APPLYING HOMOGRAFTS

Wounds have to be as clean for homografts to take and grow as for autografts No useful purpose will be served by putting homografts over areas of slough or on dirty or infected wounds.

Wounds are prepared for grafting as described in Chapters 4 and 7 It is often to the ultimate advantage of the patient to use a few extra units of blood so that the slough can be removed rapidly with the knife and the wounds sealed with homografts and thereby avoid a long period of chronic debilitation.

If the burned areas are quite extensive so that the patient cannot withstand early surgical débridement of all of it the work can be broken up into stages débriding one extremity (or even half of it or a comparable area) at a time homografting it and a few days later débriding another area In general however it is often best to employ 2 or 3 days of cleansing care and dressing between the time of knife débridement and application of homografts to a specific area

The homografts can be fresh ones, or preserved postmortem grafts from a skin bank the latter method is employed routinely on our service The use of a bank means that the patient can have the grafts applied when

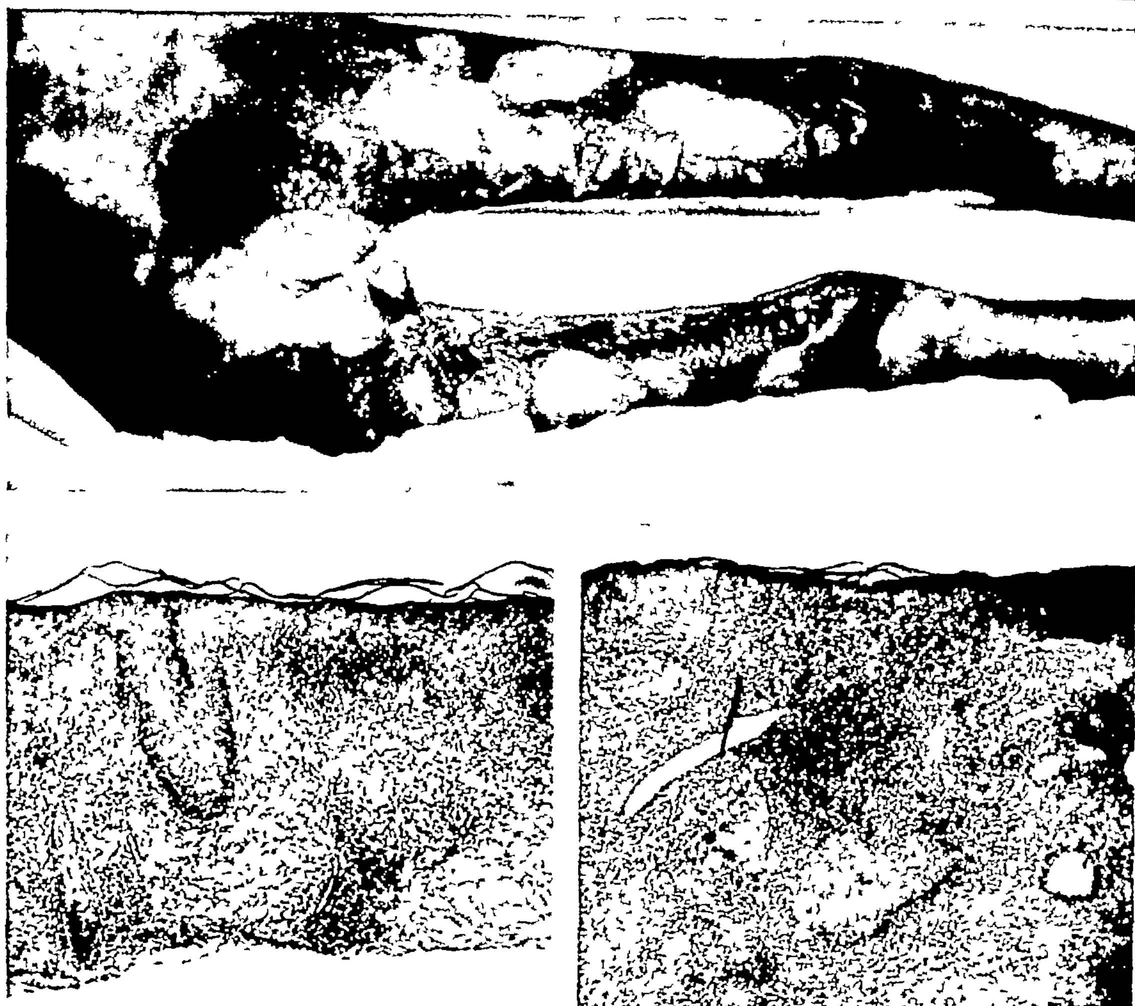


FIG 232 (*Top*) Homografts thought to be lifesaving (same patient as in Figs 229-231) Shows gross, clean absorption of homografts after 3 weeks (the last one persisted almost 11 weeks) (*Bottom, left*) Biopsy of 3-week-old homograft which appeared grossly normal Shows marked interstitial edema throughout, with little cellular reaction (*Bottom, right*) Homograft biopsy at 5 weeks, when small holes were appearing in the grafts Shows marked cellular infiltration with beginning solution and fragmentation of derma and epithelium Higher power shows so many eosinophiles that it would be a good place in which to study this type of cell Various round cells and polymorphonuclears also present

he needs them and when his wounds are in optimum condition to receive them, rather than at some haphazard moment when a skin donor may be available

At the time of application, the recipient's wounds are washed gently with saline (not with soap or a detergent); the surrounding skin may be washed with soap and water, and sometimes a final light cleansing with ether. Homografts in as large sheets as possible are obtained from the bank and smoothed out over the raw areas, there is very little point of using small scraps or "stamps" of homograft If the patient's condition will tolerate it, some sheets of autograft may be cut at this time, and the wounds may be covered with alternating strips of homograft and autograft, using homograft strips adjacent to both lateral margins of the defect

The grafts are wrapped firmly and smoothly in place with a roller bandage of fine-mesh grease gauze by the "snubbing technic", no sutures are used An over-all large pressure dressing is applied outside this, with splinting where necessary, in the

same manner as for autografts Unless other débriding or autografting is being done simultaneously, the work may be carried out with only a basal narcotic rather than general anesthesia

The later dressings and aftercare of the grafts is the same as for autografts

When the homografts disintegrate after some weeks, they can be replaced in whole or in part with autografts, as the circum stances indicate, and the remaining open areas, if any, covered with homografts Disintegrating homografts come loose rapidly and cleanly, and it is seldom necessary to do anything more than wash them vigor ously with a saline sponge, the resulting bed is clean and is very receptive toward autografts or new homografts

MECHANISM OF DISSOLUTION[1]

The mechanism of dissolution of the grafts is interesting (Fig. 232) as it usually is not accompanied by elevation of tem perature, cellulitis, or pus formation Biopsies taken early in the process show inter stitial edema, with slight cellular infiltration, as might be seen in an urticarial wheal Later the interstitial edema is less striking and the cellular infiltration becomes heavy, consisting chiefly of round cells with many eosinophils and some polymorphonuclear cells This heavy cellular infiltration coin cides with the disappearance of various dermal elements and epithelium in scattered areas Grossly the graft has numerous tiny areas of loss and appears 'moth-eaten" at this time. These areas increase in number and coalesce until final complete solution of the graft occurs.

It would appear that the proteins in the homograft are antigenic and that the host requires about 3 weeks to build up a maxi mal allergic response or immunity to them If a second crop of homografts from the same donor were applied to the patient at this time one would expect almost complete failure to take. By the same reasoning, any previous attempts to "desensitize the pa tient to the donor's skin proteins probably would decrease the chances of take Con versely, attempts to "denature' the antige nicity of the proteins in a homograft or to change them by previous immersion in the patient's serum have not proved to be clini cally successful in skin grafts, in our experi ence as well as that of others

"Take" and "permanent survival" of homografts are frequently confused in the literature, even by those who should know better, this is frequently compounded by the statement that such grafts are "successful," without elaboration of what is meant by that term

"Takes should be routine when skin homografts (i.e., grafts from one individual to another of the same species) are done properly

"Permanent survival" of skin homografts in humans has been authenticated in identical twins (Fig 239), and in some cases of a-gamma-globulinemia. Other instances have been reported but are open to question As the homografts disintegrate, there is frequently rapid ingrowth of epithelium from surrounding skin or autografts, and connective tissue up from below, to replace the homograft in situ by scar in exactly the same gross pattern Thus, such strips of apparent homograft may be seen years later but usually are composed mostly of scar This is known as creeping replacement.

The usual duration of persistence of skin homografts in humans is from 3 to 10 weeks (Fig. 232), with occasional in stances of persistence for a few months.

Laboratory animal investigations have been pursued in almost every plastic surgi cal center to try to find some method to get homografts to persist (or patients to tol erate them permanently), but so far they have been without success. Sometimes per sistence can be prolonged by large doses of "anti-allergy" drugs such as the antihista mines, ACTH cortisone, etc., or by block

[1] First published in this book in 1943

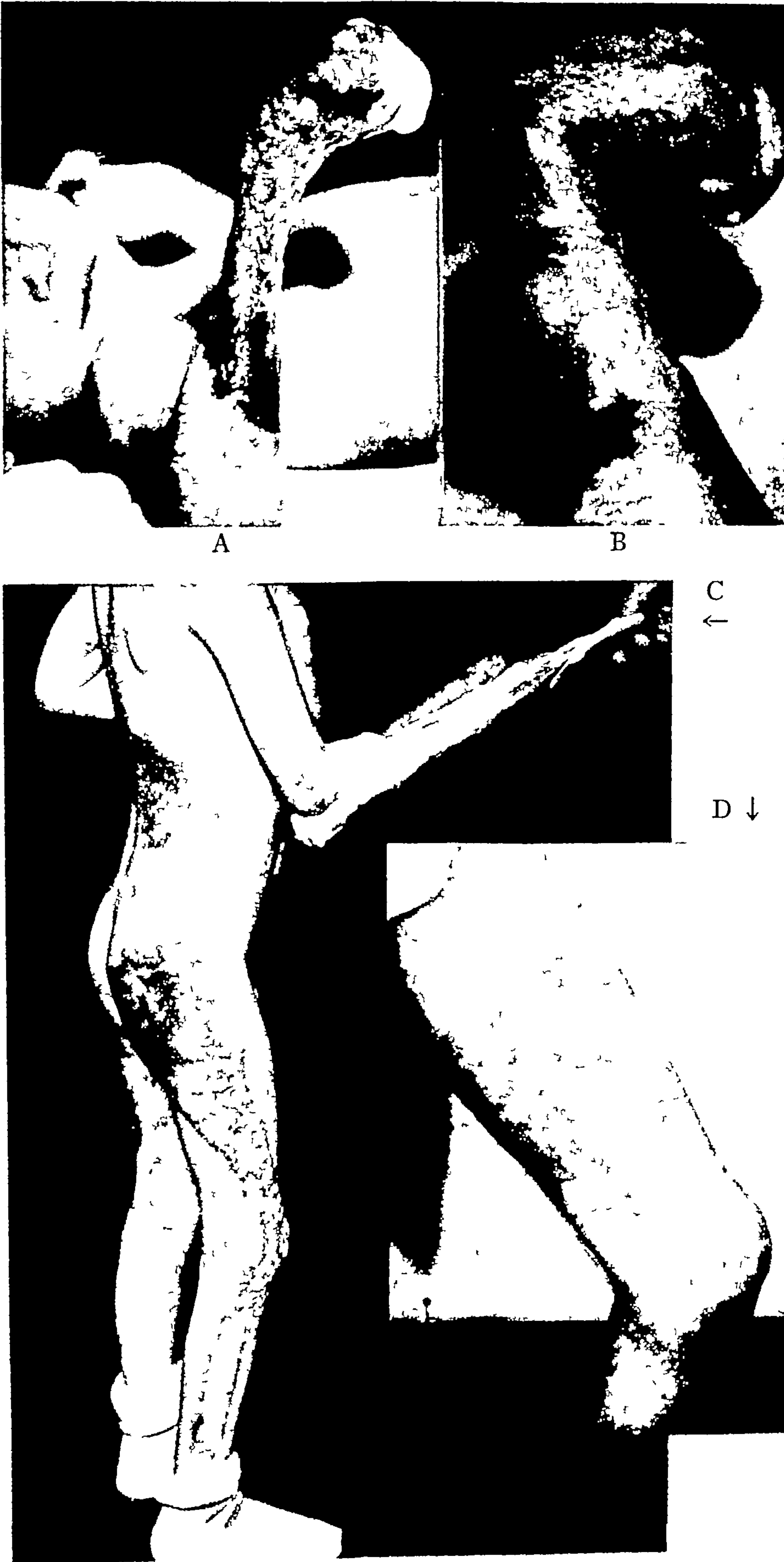


FIG 233 Debilitated child with severe burns of right lower and upper extremities Intractable to the point of having had amputation considered (A and B) Coverage, in the position of deformity, with own split grafts to obtain healing of arm Homografts from father used at same operation to cover the leg temporarily (C) Completely healed, only two operations, with his own grafts from the back and the abdomen The hand opened out and further grafting at second operation, when the leg was covered with his own grafts (D) Donor site of homografts on the father (Ann Surg 115 662)



FIG 234 (Same patient as in Fig 233) (*Top*) Original 90° flexion deformity from secondary contracture Death may occur in this stage, and the work of cleansing the areas and getting patient ready for operation, at times, seems to be insurmountable (*Center*) Leg "dressed" in split homografts from father Complete "take" and coverage 3 weeks postoperative (*Bottom*) Homografts still present after 6 weeks but beginning to melt away Improvement can be measured by the fact that the patient has opened his 90° flexion deformity spontaneously The whole area was restored later with his own grafts as shown in Figure 233 C (Ann Surg 115 663)

ing or knocking out the reticuloendothelial system by sublethal general body radiation or other methods but even these slight gains are not practical for use on patients However it is hoped that eventually some new and useful method will be developed

According to Dr Leo Loeb, no two individuals are exactly alike, and in the light of our present knowledge there is little reason to expect homografts to survive permanently

Homografts in identical twins, how

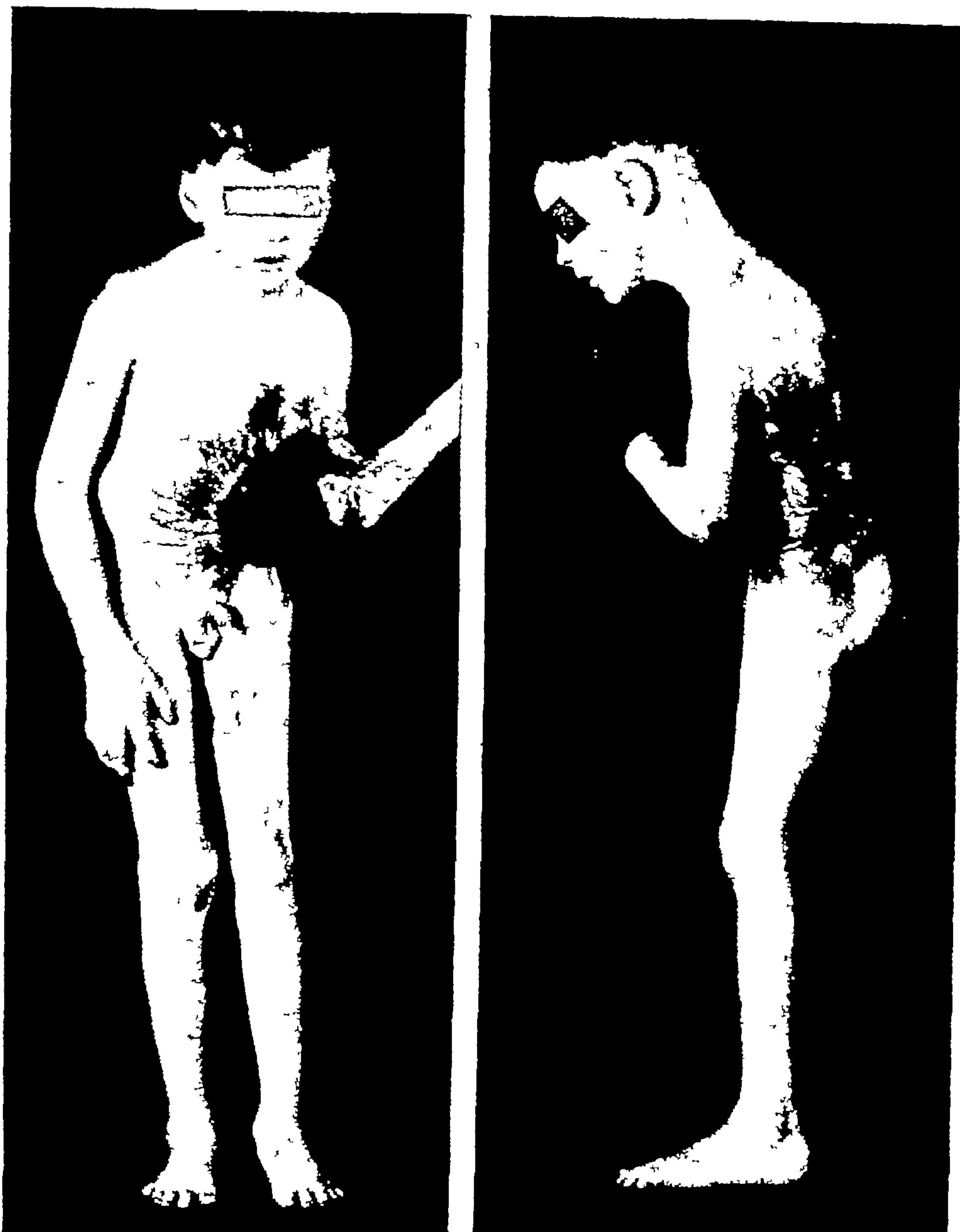


FIG 235 Deep burn extending close to the peritoneum Reaction to any type of treatment was extremely bad, and general health declined so rapidly that it was feared that he would not survive (Surgery 1 558)

ever, have been shown to survive (Fig 239), and if a twin were burned, probably the other one could be used satisfactorily as a donor.

SECURING PERMISSION TO CUT POSTMORTEM HOMOGRAFTS

The advantages of obtaining from a single patient after death large sheets of split-skin homografts versus the disadvantages of obtaining a similar large amount from live donors are almost too obvious to mention but in development of a plan many important considerations arise

Permission for such postmortem homografts should not be difficult to obtain, either along with, or without, request for a general autopsy The responsible relatives may be shown the need by attending a dressing of a severely burned child, or by being shown photographs of what is needed and what might be accomplished Death of a relative at a time of need would supply a most acceptable source of postmortem homografts, and it is possible that some patients near death may request use of their own skin.

A person who dies may save the life of



FIG 236 (*Left*) Same patient as Figure 235 After homografting the patient improved, and following their absorption there was fairly rapid spontaneous healing with the deformity shown. This phenomenon is sometimes mistaken for persistence of the homografts but can be differentiated by frequent observation of the wounds during the period (*Right*) Final repair with thick split autografts from the thigh to the axilla the arm the chest and the abdomen. (Surgery 1 558)

another person even after his own death is the essential idea of this method and in furthering general acceptance of it expression of thanks, by parental words from the recipient family, or by letter, or even a small certificate from the service involved, may be considered From a practical standpoint of directness and effectiveness in a surgical emergency from personal, ethical and other standpoints no adverse points have been found that will hold up in comparison with the general good

Co-operation of pathology departments is necessary, and also of other services for contact with relatives of patients who have died Statutes may be found concerning such a procedure that can be met on a local basis

Understanding and responsibility of the recipient and the relatives is important to establish, but except for the bizarre uneducated or chronic litigant, there should be no difficulty in the face of a critical burn or denudation of skin

Selection of donors is important in protection of the recipient and in allaying natural suspicion Obviously, the postmortem donor should be free of lesions, diseases, allergies or dyscrasias that might be detri

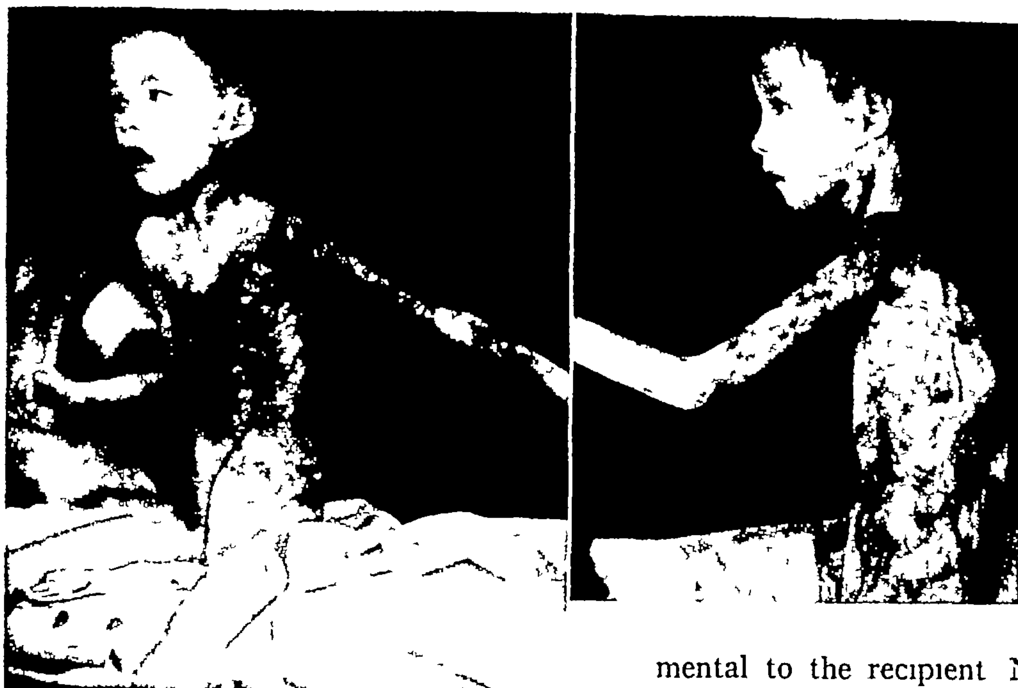


FIG 237 Lifesaving by homografting (*Top, left*) Patient debilitated almost to the point of death by huge open wound (*Top, right*) Appearance 2 weeks later after coverage of the arm with split grafts from her own thigh and temporary coverage of raw body area with homografts Facies even shows that the patient is now on the road to getting well after a short interval These homografts underwent dissolution after from 5 to 6 weeks and were then replaced with split grafts from her own thighs (*Bottom*) Final appearance 3 years later, showing surgical rehabilitation and permanence of the result



mental to the recipient Necessarily, complete records on the histories of both donor and recipient are made and, naturally, negative serology of the donor will be one of the most important records

Complete release of bodies for investigation might be a source of these grafts, except that such arrangements are usually delayed until after complete death, so that the skin would no longer be useful as a graft.

Armed services could record of each member if permission for such a procedure would be granted in case of death, civilians could declare their wishes in case of death by a central registry, and thus in case of severe emergency the mechanism for obtaining large amounts of the best possible "biologic dressing" would be established This would seem as practical and as easy of public acceptance and of implementing as the Red Cross's obtaining blood from live donors

National defense could include studies and direction of a national plan for this procedure But local adaptation is possible even for small hospitals or for the individual patient in need The main idea is to try to save the life of each individual burned patient and this does not require anything but proximity to, availability of, and mechanism for transferring skin from a patient who has just died to one in need

At a national defense level the need would be mainly to educate the public to accept



FIG 238 Lifesaving with postmortem homografts. (*Left top*) A patient moribund from a huge burn, with little chance of surviving. Burn slough was removed and postmortem homografts (from refrigerated body 7 hours after death) were applied 9 days later (*Right top*) Six days after homograft coverage, with marked improvement in general condition. (*Left bottom*) Thirty days after homograft coverage, with good persistence and further improvement in general condition so that autografts have now been cut from right lower abdomen (*Right bottom*) Final healing with all areas covered with autograft in stages. This patient was cared for by Dr Minot Fryer

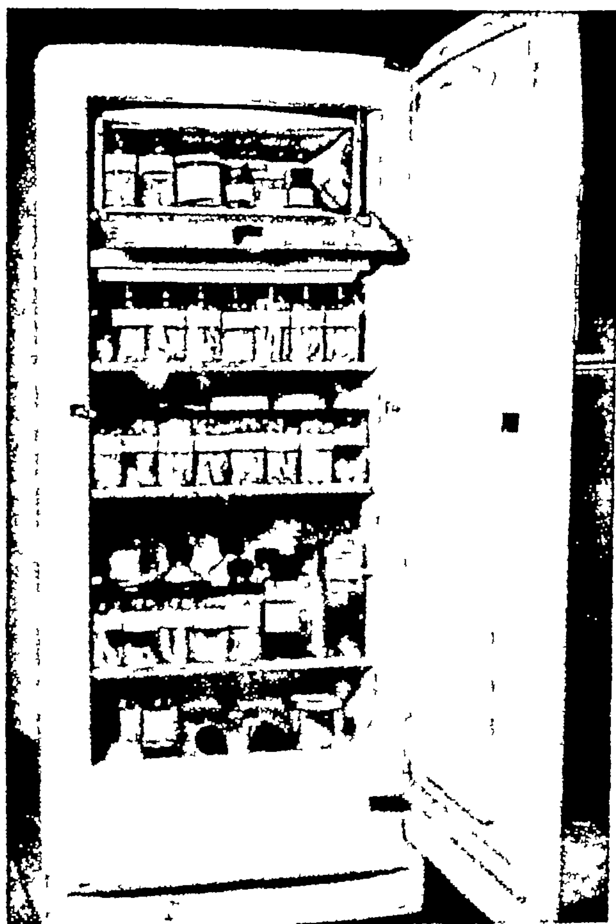
ance, and to the possible development of a central registry and collecting agency, if methods of preservation proved to be successful This might even be included in the blood donor notation The thought may be unpleasant but this should be a matter of example explaining possible need and of letting the public in general know how truly horrible severe burns and skin losses can be and of the extreme cost of their care. Put in a plain way a large amount of good, usable skin is going to waste that could be lifesaving if the details of procurement and application of postmortem homografts are worked out.

THE TECHNIC OF CUTTING POSTMORTEM HOMOGRAFTS

It is usually best to secure the grafts within 1 or 2 hours after systemic death when possible If the body is refrigerated promptly living grafts can be removed up to 12 hours or more, but it is more difficult to smooth out surface irregularities and cut large grafts from a frozen body

The grafts are obtained by the usual

Fig 239 Complete and permanent survival of full-thickness homografts interchanged between identical twins Grafts still persist with border scar around them after 8 years (Surgery 1 588)



aseptic surgical technic, preparing the skin with antiseptics, using sterile drapes, gowns, gloves, etc The exact locale of operation is not too important The work may be done in an operating room, or in a pathology laboratory, if satisfactory preparations are made

The best sites for grafts are the back and the thighs, as in the living patient

Any graft-cutting instrument can be used, but a glue dermatome is rather tedious The

Fig 240 Simple skin bank for living homografts of skin, using an ordinary electric refrigerator kept at 4° C. Different areas for various methods and nutrient media. Upper compartment for storage at —20° C About 30,000 square inches of skin can be stored in this unit

largest grafts can be obtained the most rapidly by free-hand cutting with a large knife, and the use of suction retractors The next best method is probably the electrodermatome. In any event it is important to cut thin grafts and in large sizes—the larger the better

Usually the grafts are folded carefully on themselves and wrapped in sterile damp saline sponges or spread out on a damp roller bandage and then wrapped around a sterile test tube then the entire group may be wrapped in a sterile towel and transported to the operating room for immediate use or to the skin bank for preservation

LABORATORY INVESTIGATIONS

Laboratory investigations have been and are being carried out, among which are further studies on homografts in general determination of limits of viability and usefulness of postmortem grafts and problems of preservation and possible persistence

The period of viability of skin left on the postmortem donor and preserved after removal can be tested by use of the chick embryo but a more evident method has been developed by using mice for growing the human skin This might be called a "reversed zoograft." Human skin grafts will take completely on denuded areas of the mouse (or other laboratory animals) and can be seen to survive about 30 days Biopsies can be done and the viability established by microscopic study

Laboratory animals don't lend themselves to very parallel situations of human grafting however and good clinical observations with appropriate microscopic studies are apt to be of most value. Animal skin is not much like human (except in pigs) hair is a nuisance and the platysma arrangement of animal skin does not have much counterpart in humans. Dressings and care and sterile precautions cannot be the same, and animals degenerate so quickly after death that observations may be missed The human needs for skin grafts are also difficult to reproduce in animals

Survival of skin for some time after systemic (or somatic) death is recognized, and for most practical purposes the skin can be stored, by being wrapped up in the ice box for several days without nutrient Ten per cent plasma probably increases its length of life but the exact extent is not finally determined A wide range of time of post mortem viability is reported in the literature That skin can be "stored" on the patient after death and used at appropriate times is a practical answer to the storage problem, but more factual and final determinations are being studied to set limits on body storage after death storage by simple cooling after removal from the body and a main problem to be met is how long freezing will preserve skin so that it may act as a successful homograft

Needless to say the major benefit would be to find some method of arriving at permanent survival of homografts so that the unfortunate patient could walk around permanently in his benefactor's "skin clothing" But so far in humans this is possible only in identical twins. Mice can be so inbred as to establish the effect of identical twins in the permanent survival of homografts such as Bar Harbor C 57 and there may be other animals or birds or cold blooded animals that may carry on in happy symbiosis or incorporate as their own living tissues elements from others of their species But so far the human seems to be individual enough to stand or fall on his own tissues. It seems sad that this is so, but philosophically it seems that the Lord did not intend his creatures to tear and maim and burn themselves so far that there would be need for complete regeneration of damaged and lost parts.

So far there seems to be no authentic series of permanent persistence of homotransplants except in identical twins or inbred species in warm blooded animals In other words, an agent has not been found that will make us all alike.

Postmortem homografts were first done on this service in 1927, when it was thought worthwhile to see if fetal skin homografts might be retained permanently Using immediate postmortem grafts from a 7-month fetus that had lived 24 hours, there was the usual complete take of the homograft, followed by the usual complete absorption in 4 weeks, so that it was seen that there was no reason for expecting fetal grafts to survive permanently any more than other homografts

Dressing of burns in homografts as a life-saving emergency was reported in 1942 Permanent survival of homografts in identical twins was obtained in 1932 and reported in 1937 (Fig 239)

Postmortem homografts were used on one occasion at Valley Forge Hospital, working with Dr Bradford Cannon and Dr Andrew Moore and others on the service They were used as immediate grafts, taken a few hours after a suicide, and were lifesaving for an officer who had lost the entire skin of the head, the face and the hands Recent efforts have been made to go ahead with development of this procedure and to try to work out the multiple facets of procurement of grafts, transfer to patients, storage, influencing the public to accept the idea, and of course, further attempts for permanent survival

Literature Our first postmortem graft in 1927 was done without resort to the literature, but it was realized that the use of postmortem material occurred to many independently and probably as far back as Galen There are a few references in the literature from Russia to the Argentine, but so far, no very orderly or outstanding information has been found Girdner stated that he was the first to use "cadaver" grafts in 1881, reporting one instance of grafts, taken 6 hours after suicide, for a patient burned by lightning Schede in 1881 reported grafts from amputations and fresh cadavers with a 12-hour limit on removal of the graft Bartens, in 1888, used immediate postmortem graft from a patient, dead of "septicemia" (?), which was unsuccessful.

Needless work has been done and hap hazard ideas expressed, as shown in the fact that most of the areas requiring grafts were so small that there was no reason for using other than fresh autografts, the work presumably having been done on patients as investigation In a recent report, the patients needed such small grafts as to make the use of postmortem grafts unnecessary and useless

The differentiation of "take" and of "permanent survival" of homografts has had little attention paid to it in the literature of homografting in general, and this lack of recognition is true today One of the longest and most authoritative works on skin graft states, " my own personal experience convinces me that isodermic grafts (homo) are quite as successful as those from the same individual, under similar favorable conditions, this applies especially to isodermic whole thickness grafts, although Thiersch grafts have also healed well " Such statements may cause query of reliability of other statements in the long article

Ivanova, in 1890, reported postmortem grafts 2 hours after death for a burned leg, with observation that speedy and sound healing ensued but, as usual, without statement as to how long the homografts persisted Gluck reported use of postmortem grafts since 1876 with "good results " Good results is in quotes because he claimed them even after storing grafts in 10 per cent formaline, and keeping them cool 2 years; and he also used frog, turkey and rabbit skin Davis, in 1910, mentioned such use, but did not mention permanent survival observations or indicate in his report of 550 grafts that any were of postmortem origin Calot, in 1913, mentioned use of postmortem Thiersch grafts and did not think time of removal after death was important. Minervini, in 1913, reported use of newborn and fetal skin Bianchi, in 1945 and 1947, used

grafts taken several days after death with vital dyes for vitality tests and reported "numerous" grafts with success Catalano in 1947, mentioned one patient who did not grow her own autografts but did grow grafts from cadaver, with the usual lack of note of persistence In 1947 he assumed that a postmortem homograft survived indefinitely when blood groups of donor and recipient were the same Dogo, in 1952 used the Warburg method of testing vitality and reported 27 positive results from 7 cadavers taking skin up to 16 hours postmortem, with survivals of grafts from 7 to 22 days The 6 patients discussed had small lesions that could have had autografts without the extra work of homografting

The above references are a partial cross section of the reports to date, Rogers is referred to for the fullest recent bibliography on homografts

As a substitute for skin, Davis in 1910 reported work on amniotic membranes and others including Douglas have carried this on with promise

Animal skin probably can be successfully transferred to humans for a short life there as zoo grafts, but so far the reports of attempts have been so bizarre as to negate them for the present

Other tissues than skin have been used and still others may be considered for use from such immediate postmortem source whether used immediately or preserved for example, cartilage fascia bone, tendon cornea nerve veins and arteries, organs glands of internal secretion and possibly even the salvaging of blood

Autotissue culture is another phase of investigation endeavoring to avoid the use of homografts However even if it could be found possible to grow sheets of human epithelial skin cells in culture these might not prove to be of permanent practical use because all of the layers of the skin including the dermal pad especially, are necessary for normal function. However such sheets might be used for temporary sealing of wounds if a satisfactory method of abrasive or other removal were also devised otherwise homotissue cultures might have some advantages

SKIN BANKS

A skin bank is worthwhile on any service that treats a considerable number of large deep burns It need not be on an extensive scale but can be a simple project designed to furnish large sheets of homografts for temporary coverage of large wounds whenever needed

Split-skin postmortem homografts are the assets of such a bank Much experimental work is being carried out to find the best methods for the longest preservation of such grafts consequently, no final recommendation on this is possible at the present time Apparently preserved living grafts are better than preserved dead grafts for sealing wounds, but even this point is not entirely certain

One of the key points is that experimental work on animal skin is not identical with the results obtained on human skin, and that work on other tissues (e.g, cartilage or arteries) cannot always be carried over with the same results on skin Experiments involving zoografting are interesting but complicate the analysis. The final efficiency of any method will have to be judged in terms of large human split skin homografts sealing wounds on living human patients

Methods being tried include partial dehydration of the grafts in a vacuum or in various hygroscopic media. This may be combined with low temperatures, from just above freezing to far below freezing and at varying rates of freezing and thawing to try to prevent cellular disruption from ice crystals Work is also being carried out on various nutrient media, but no final clinical evaluation is available yet on a large scale

Until the best method is worked out, a simple bank can be maintained to preserve homografts for short periods This can con

sist of an ordinary small electric refrigerator placed somewhere in the operating suite, used solely for this purpose and attended daily and continuously by some one responsible individual (Fig 240) The temperature is maintained constantly at 4° C Postmortem homografts are obtained with sterile and other precautions, as outlined before Each graft is wrapped in a damp (not wet) saline sponge, which in turn is wrapped in one or two layers of grease gauze and then in a sheet of plastic material (e g , pliofilm, or something similar) The package is labeled on the outside as to the date and the donor and placed in the refrigerator The loss of ability of these grafts to seal wounds follows a curve, with a gentle downward slope between 1 and 3 weeks, and a precipitous decline around 3 weeks Grafts are generally used any time during the first 3 weeks, and any remaining ones are discarded when they become 3 weeks old

This seems to be almost too crude and simple to describe and recommend and undoubtedly will be replaced soon by superior methods, but in the meantime it will save lives in severely burned patients When any such patient is admitted to the hospital, efforts can be started toward procuring postmortem homografts for him and preserving them The grafts are then available for immediate application as soon as his wounds can be made ready to receive them

Skin Banking at 3° to 5° C.

Fresh skin homografts remain viable for about 21 days when folded on saline antibiotic gauze sponges and stored at ordinary household refrigerator temperatures Some take of these refrigerator stored homografts is possible after a month but becomes progressively poorer after 3 weeks

This is the simplest method of banking A minimum of time and materials is required, and ordinary refrigerator temperatures are readily available When needed, these grafts are removed from the refrigerator and are ready for immediate use on the recipient's open areas.

If these grafts are not used in 3 weeks, they are processed and stored at low temperatures or lyophilized. The desirability of expanding this double storage method is being investigated

Nutrient media added to saline-antibiotic solution lengthens the survival time of postmortem grafts stored at 3° to 5° C. temperatures enough to be considered practical The most satisfactory mixture of this type appears to be 10 per cent serum or plasma added to buffered normal saline with 50 units of penicillin and streptomycin per cc Blood cells are not used, as they contribute to the acidification of the media When phenol red is used as an indicator, color change denotes lowering of the PH from accumulated cellular metabolites The media usually requires change about every 8 weeks, or when it becomes cloudy or contaminated Hyatt reported the take and the persistence of homografts preserved in plasma in Earle's solution at 3° C for 6 months comparable with fresh homografts The grafts, wrapped in gauze, may be covered with this medium or merely moistened Allgower and Blocker reported optimum viability when medium volume was 1 cc for each sq cm of skin Exclusion of oxygen is detrimental to the grafts

Adenosine, which is reported to have more than doubled the viability period of stored blood cells, may have promise in skin preservation, and investigations of this are being continued

Skin Banking at Low Temperatures

There are numerous reports on low temperature storage suggesting preservation of viability of grafts for long periods However, there seems to be confusion of observation of viability and of apparent "take" in the few clinical reports

Glycerol has been used because of its "antifreeze-antithaw" action in low temperature banking Treatment of the skin with 15 per cent glycerol in Earle's and Ringer's solutions with various combinations of nutrient media has been done before

storage at —10 , —20°, —40° and at —79° C

The following is a description of this method of use and storage for skin preservation Split skin grafts are placed for 1 to 1½ hours in one of the glycerol solutions. After blotting the grafts with gauze they are placed in a glass jar Placing this jar in a second container provides an air jacket for the slow lowering of the temperature of the graft in a dry ice-alcohol mixture (—79° C) When this temperature has been reached the inner jar is used for storage. As they are needed these grafts are thawed rapidly by immersing the jar in a 37° C water bath or by placing the grafts directly in sterile Ringer s solution kept at 37° C until they are completely thawed. After thawing the glycerol is removed by placing the grafts in Ringer s or Earle s solution for 1 hour at room temperature before use

It may be possible that skin could be exposed to —79° C., banked at this temperature for prolonged periods of time and then thawed with survival of the major portion of the cells Rapid thawing gives better viability than slow thawing Slow (air chamber) cooling seems to give better viability than rapid cooling Though there may be cellular damage and breakdown at —79 C and even at —180° C., these cellular processes are slowed down and preservation may be possible for prolonged periods of time Deterioration of skin thawed from this temperature is more rapid than that of fresh skin

It is known that isolated epidermal cells will survive exposure to 90 per cent glycerol for 8 hours at 0 C and 80 per cent glycerol for 2 hours at room temperature Skin is protected against the killing effects of low temperature and thawing by the use of glycerol but the exact mechanism is not certain

Dehydration occurs there is change in the structure of the low temperature solid the freezing point of water is lowered with the glycerol promoting supercooling by its own viscosity Effectiveness of the glycerol probably depends on its diffusing into the cells of the graft Various cells may differ in their permeability to glycerol A large mass of cells as in a skin graft will take a longer time for the glycerol to permeate it than small isolated groups of cells The clinical criteria of successful glycerol preservation is the successful preservation of viability at low temperatures

Thawing is more damaging to skin than freezing Diathermy has been used for very rapid thawing of tissues but in some instances has not been found to thaw tissues fast enough Lovelock has suggested a radar type of apparatus for rapid thawing

Medawar has reported survival of rabbit skin up to 500 days or longer at —79° C after impregnation with glycerol before temperature reduction of the banked grafts. These grafts used as autografts did not show any distinguishable changes from unstored skin grafts in fine structure Controls which had been pretreated with Ringer s solution or saline alone are inferior

Low temperature storage without glycerol is being investigated Skoog has reported experimental storage at —70° C. up to 28 weeks After thawing relatively constant oxygen consumption by the Bancroft Warburg methods was noted He also reported three successful clinical takes of homografts stored at —70° C for 13 months.

Autografts stored at —20° C to —25° C covered with citrated plasma and thawed with a water bath at 37° C were reported by Strumia and Hodge to take almost as well as fresh autografts up to 61 days

Vitrification

Ultrarapid cooling leads to vitrification and is thought by some to be theoretically preferred because of the belief that the formation of ice crystals is prevented eliminating the mechanical damage to the cells by these crystals Luyet has carried out extensive studies showing viability of various cells and tissues after ultrarapid freezing and thawing

Skin has been ultrarapidly cooled after precooling to just above the freezing point Temperature lowering is secured by dropping the grafts into liquid nitrogen (−196° C) Results can be improved by partial dehydration with ethylene glycol Since the speed of cooling required to vitrify varies with the water content, this preliminary dehydration facilitates vitrification The skin after ultrarapid cooling was stored at −70° C A high percentage of survival after 44 and 66 days but not after 123 days is reported by Keeley, Gomez, and Brown Buchanan reports no difference from fresh controls in dog skin which was "quick frozen to −190° C , kept up to 1 hour and autografted

Better viability in mammalian skin is maintained by banking after slowly lowering the temperature of the grafts than by ultrarapid methods Pryde and Jones report that vitrification of water is difficult to secure and it will remain in the vitreous state only at temperatures below −130° C , changing to ice in crystal form above this temperature

LYOPHILIZATION (FREEZE DRYING)

Lyophilization occurs when skin is frozen and then under high vacuum the ice is evaporated without melting to a low temperature condensor Lyophilization of skin may become a practical long-term storage of nonviable skin, as it has with blood vessels

Webster used lyophilized skin as an autograft and reported an 80 per cent take after 17 days' preservation, stating, "There is no question of fact that this skin graft, *which was frozen at −72° C and dried by the lyophilizing process*, actually survived this treatment and persisted as *living skin*, although it was a less satisfactory transplant than the control fresh graft that was immediately transplanted."

The possibility of some cells surviving such processes is being investigated and to be most sure autografts are used, or inbred animals in which homografts will survive Grafts from such animals have been called isografts by Dr R. M. Merwein and the group working at the National Health Institute This seems to be a good designation for these inbred animal grafts to distinguish from actual autografts and to shorten the explanation necessary otherwise

Rabbit skin does not remain viable in drying from the frozen state to below 25 per cent final water content, and as yet no mammalian tissues have been found to withstand drying to below 10 per cent residual moisture content Tissue culture has not been able to demonstrate living cells in lyophilized skin, which has been dehydrated to the total water content of less than 1 per cent Gross appearance of the lyophilized skin is misleading as to the dryness, and the final water content should be determined to substantiate the degree of lyophilization

Freeze-dried skin is reported by Hyatt to be an excellent means of long-term skin preservation, which will serve as temporary wound coverage as well as fresh homografts Lyophilized skin can be stored on a shelf at room temperature, is easily transported, remains stable for prolonged periods of time and is easily prepared for use by the addition of saline for 30 minutes prior to use Lyophilized skin was used on a young patient, lasted approximately 2 weeks, but Hyatt reports that this skin did seem to disappear earlier than homografts from multiple donors which had been preserved in balanced salt solution

After freeze-dry skin is moistened, it has the gross appearance of a fresh split-skin graft Pate used lyophilized skin on 20 patients and stated that no surgeon could distinguish freeze-dried skin from a fresh homograft

Desi[illegible] ra[illegible] ozen state were t[illegible] plasma hydrati[illegible] an and persiste[illegible] to 22 days. T[illegible] raft [illegible] the

time of preservation Trial on one patient suggests that it may prove to be of value as a temporary covering since the skin persisted for 12 days, after which the patient died of complications

The technic of lyophilization is essentially the same as reported by Creech DeBakey and Cooley Changes in details of this fundamental procedure are made frequently but report is made of this for completeness.

Skin grafts can be taken under sterile conditions, but when necessary they may be passed through several basins containing antibiotic-saline solution Spreading the grafts over a firm coarse, wrinkled gauze material will obtain maximum surface exposure and free air circulation during drying After the skin has been placed in containers liquid ethylene-oxide is added and poured off after 20 minutes if an antiseptic is thought to be necessary These containers are then placed in a dry ice–acetone mixture and connected to the lyophilizer When the process has been completed the tubes are vacuum sealed and stored on a shelf at room temperature

Formerly many hours were needed to effectively freeze-dry skin Recent modifications of technic and the use of an efficient freeze-drying apparatus manufactured by the American Instrument Co., which has outlets for 25 tubes drying is complete (less than 1% water content) in less than 3 hours time When the skin is needed reconstitution is done by soaking the skin for 30 minutes in a 37 C saline solution containing 500 000 units of penicillin and 1 Gm of streptomycin to the liter

Viability Determinations

Human skin will take and persist on the experimental mouse for 15 to 30 days and with good repeated clinical observation has proved to be a valuable means for viability studies Methods of preservation and storage temperatures and nutrient influences can be studied.

Final decision of persistence may depend upon the use of autografts from the animals themselves or on inbred animals that permanently retain homografts from one another, since homografts prepared by nonviable methods may last almost as long on the wound as known viable homografts The increasing accuracy of repeated observation and the appearance at the time of ultimate loss of the graft may make this a method of unquestioned reliability for all observers

Tissue culture is stated by Pomerat to be the best test of skin viability, since there is no question of confusing marginal or deep tissue growth with persistent transplant

Growth of human skin on the chorio-allantois membrane was reported by Goodpasture, Douglas and Anderson and this was confirmed by Tenery and McDowell

The importance of viability in homografts is being investigated clinically and the results studied *Viable homografts* provide a more normal type coverage may spread out some, last longer, establish a completely healed wound which requires infrequent dressing change or no dressing at all and eventual loss is complete with minimal amount of drainage *Lyophilized skin* is more practical for storage and transportation and because of this might be of more value in a national emergency or for the Armed Services Loss of this membrane appears to be continuous with constant drainage and the deeper layers of the transplant may require eventual excision before the open areas can be covered with autografts

Present Recommendations for a Bank

To anyone caring for numbers of large burns, the advantages of a skin bank for postmortem homografts are too great to wait for elaborate quarters or apparatus or grants of money from the government or some foundation

All that is really needed is a reliable refrigerator that can be kept at 4° C. and the will to make the project succeed

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Lyophilization (Freeze Drying)

Lyophilization occurs when skin is frozen and then under high vacuum the ice is evaporated without melting to a low temperature condensor Lyophilization of skin may become a practical long-term storage of nonviable skin, as it has with blood vessels

Webster used lyophilized skin as an autograft and reported an 80 per cent take after 17 days' preservation, stating, "There is no question of fact that this skin graft, *which was frozen at —72° C and dried by the lyophilizing process*, actually survived this treatment and persisted as *living skin*, although it was a less satisfactory transplant than the control fresh graft that was immediately transplanted "

The possibility of some cells surviving such processes is being investigated and to be most sure autografts are used, or inbred animals in which homografts will survive Grafts from such animals have been called isografts by Dr R M Merwein and the group working at the National Health Institute This seems to be a good designation for these inbred animal grafts to distinguish from actual autografts and to shorten the explanation necessary otherwise

Rabbit skin does not remain viable in drying from the frozen state to below 25 per cent final water content, and as yet no mammalian tissues have been found to withstand drying to below 10 per cent residual moisture content Tissue culture has not been able to demonstrate living cells in lyophilized skin, which has been dehydrated to the total water content of less than 1 per cent Gross appearance of the lyophilized skin is misleading as to the dryness, and the final water content should be determined to substantiate the degree of lyophilization

Freeze-dried skin is reported by Hyatt to be an excellent means of long-term skin preservation, which will serve as temporary wound coverage as well as fresh homografts Lyophilized skin can be stored on a shelf at room temperature, is easily transported, remains stable for prolonged periods of time and is easily prepared for use by the addition of saline for 30 minutes prior to use Lyophilized skin was used on a young patient, lasted approximately 2 weeks, but Hyatt reports that this skin did seem to disappear earlier than homografts from multiple donors which had been preserved in balanced salt solution

After freeze-dry skin is moistened, it has the gross appearance of a fresh split-skin graft Pate used lyophilized skin on 20 patients and stated that no surgeon could distinguish freeze-dried skin from a fresh homograft

Desiccated skin grafts in the frozen state were transplanted in the dog after plasma hydration by Buchanan and Lehman and persisted in a grossly normal state up to 22 days They found autograft or homograft persistence has not been influenced by the

time of preservation Trial on one patient suggests that it may prove to be of value as a temporary covering since the skin persisted for 12 days, after which the patient died of complications

The technic of lyophilization is essentially the same as reported by Creech DeBakey and Cooley Changes in details of this fundamental procedure are made frequently but report is made of this for completeness

Skin grafts can be taken under sterile conditions but when necessary they may be passed through several basins containing antibiotic-saline solution Spreading the grafts over a firm coarse wrinkled gauze material will obtain maximum surface exposure and free air circulation during drying After the skin has been placed in containers liquid ethylene-oxide is added and poured off after 20 minutes if an antiseptic is thought to be necessary These containers are then placed in a dry ice-acetone mixture and connected to the lyophilizer When the process has been completed the tubes are vacuum sealed and stored on a shelf at room temperature

Formerly many hours were needed to effectively freeze-dry skin Recent modifications of technic and the use of an efficient freeze-drying apparatus manufactured by the American Instrument Co which has outlets for 25 tubes drying is complete (less than 1% water content) in less than 3 hours time When the skin is needed reconstitution is done by soaking the skin for 30 minutes in a 37 C saline solution containing 500 000 units of penicillin and 1 Gm of streptomycin to the liter

Viability Determinations

Human skin will take and persist on the experimental mouse for 15 to 30 days and with good repeated clinical observation has proved to be a valuable means for viability studies Methods of preservation and storage temperatures and nutrient influences can be studied

Final decision of persistence may depend upon the use of autografts from the animals themselves or on inbred animals that permanently retain homografts from one another, since homografts prepared by nonviable methods may last almost as long on the wound as known viable homografts. The increasing accuracy of repeated observation and the appearance at the time of ultimate loss of the graft may make this a method of unquestioned reliability for all observers

Tissue culture is stated by Pomerat to be the best test of skin viability since there is no question of confusing marginal or deep tissue growth with persistent transplant

Growth of human skin on the chorio-allantois membrane was reported by Goodpasture Douglas and Anderson and this was confirmed by Tenery and McDowell

The importance of viability in homografts is being investigated clinically and the results studied *Viable homografts* provide a more normal type coverage may spread out some, last longer establish a completely healed wound which requires infrequent dressing change or no dressing at all and eventual loss is complete with minimal amount of drainage *Lyophilized skin* is more practical for storage and transportation and because of this might be of more value in a national emergency or for the Armed Services Loss of this membrane appears to be continuous with constant drainage and the deeper layers of the transplant may require eventual excision before the open areas can be covered with autografts

Present Recommendations for a Bank

To anyone caring for numbers of large burns the advantages of a skin bank for postmortem homografts are too great to wait for elaborate quarters or apparatus or grants of money from the government or some foundation

All that is really needed is a reliable refrigerator that can be kept at 4 C. and the will to make the project succeed

Shortly after a patient with a large burn is admitted, various doctors and residents in the hospital can be notified of the need Patients who expire suddenly following head injuries, automobile accidents, or coronary or cerebrovascular episodes are the most frequent donors

Once permission is obtained in writing from the responsible relative, the grafts are cut quickly and carefully Then they may be wrapped in damp sterile sponges, surrounded by a covering of sterile waterproof material, be labeled and placed in the refrigerator

They are ready for use anytime within 1 or 2 weeks that the recipient's wounds are considered to be in optimum condition to receive them

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Restoration of Defects from Removal of Tumors

Satisfactory closure by undermining the edges and suturing or by switching local flaps is usually possible after removing small skin tumors Excision of larger tumors which have arisen in the skin or invaded it secondarily may leave such defects of such size that closure with free skin grafts or pedicle flaps is advisable Examples of the latter include large nevi port wine stains, plantar warts cancers and lymphangiomas

NEVI

Countless small nevi are removed, and the wounds are closed by local shifting of tissues Large ones may leave defects that cannot be closed in this manner without dis



Fig 241 Excision of hairy nevus of forehead and resurfacing with very thick split skin graft. Some of the nevus extended back into the hair but the excision was carried upward to where it was thought the normal hairline should be

FIG 242 Single operation repair of port-wine stain The hemangioma was dark and could not be covered satisfactorily with special cosmetics Surgically excised and covered with free full-thickness skin graft (*Right*) Result 6 months later

torting features and therefore should be closed by grafting (Fig 241) It is often best to make an accurate pattern of the nevus before removing it, as there is often a tendency for the defect to enlarge as soon as the involved skin is removed Ordinarily, a free full-thickness graft will provide the best covering, as only skin is removed in taking out these tumors Small, full-thickness grafts for the face can be taken from the lower neck, or behind the ear if it is not too red Larger ones are usually obtained from the lower abdomen or the groin Very thick split grafts from the lower anterior chest wall are often best to use Malignant melanomas require much wider and deeper excision, so these defects are also usually covered with split grafts

PORT-WINE STAINS

These should be considered as congenital anomalies of the capillary system in the derma rather than as tumors, and they are important only because of appearance Some



FIG 243 (*Left*) Congenital port-wine stain, which after many years developed into a thick, warty, bleeding hemangioma (*Right*) Result of resection and split-skin grafting.

Fig 244 (*Left*) Port wine stain of face with superimposed radiation lesion and scarring necessitating operation Failure of right nostril growth presumably is due to radiation (*Right*) Result after excision and resurfacing with free skin graft (patient has heavy cosmetics on in final photo)



of them in women can be disguised successfully with cosmetics, and when possible to do so this may be wiser than surgery Some of them may be improved by dermal injection of permanent white pigments or other chemicals (cf Bibliography Brown Cannon and Allyn McDowell 1946) They are almost uniformly insensitive to radiation in any form Destructive treatment with acids heat, freezing (carbon dioxide snow) or corrosives leaves a nasty open sore which heals by scarring and sometimes distortion, which is worse in appearance than the original lesion. Clean surgical excision and immediate replacement of the stained skin with a free full thickness or thick split graft is nearly always preferable to any of these destructive treatments but the results are not perfect and the problem should not be approached with too much optimism (Figs 242 and 243)

The stained skin is removed in the same manner that a full thickness graft is cut though there will be more bleeding The bed is made dry by prolonged pressure with warm saline packs and short judicious applications of weak epinephrine (1 5 000) sponges. The grafts are applied in the usual manner, the surgeon being sure to brush out any blood beneath them and to apply a good, firm pressure dressing Large stains are resurfaced best in stages so that a single graft does not extend from the cheek to the eyelid the nose or the lip Suture lines between the grafts can be placed in the nasolabial fold, or along the border of the nose, or the border of the eyelid It may be necessary to do secondary excisions of some of the edge scars and to inject some permanent color into the graft to make it match the rest of the face as well as possible

Occasional stains will be seen with extensive radiation effects and even squamous carcinomas developing within them These, or course require much deeper and wider excision and replacement may be with a free skin graft (Fig 244) or a pedicle flap may be required (Fig 177)

CANCER

Skin cancers that are still relatively superficial can be excised and the areas resurfaced with free skin grafts at the same operation If suitable coverage cannot be obtained by local adjustments of tissue If the lesion is infected or ulcerated a split



FIG 245. (*Left*) Extensive skin carcinoma of the nose, but still can be moved over framework (*Right*) Result of excision and split-skin grafting in one operation Result probably is superior to flap here

graft is used (Fig 245) Otherwise, a full-thickness graft may be used if it is thought that the appearance will be better (Figs 246 and 247) Deeper lesions will require deeper excisions, consequently, a pedicle flap restoration may be necessary If a delayed flap is to be used, it can be raised at the same time that the cancer is excised,

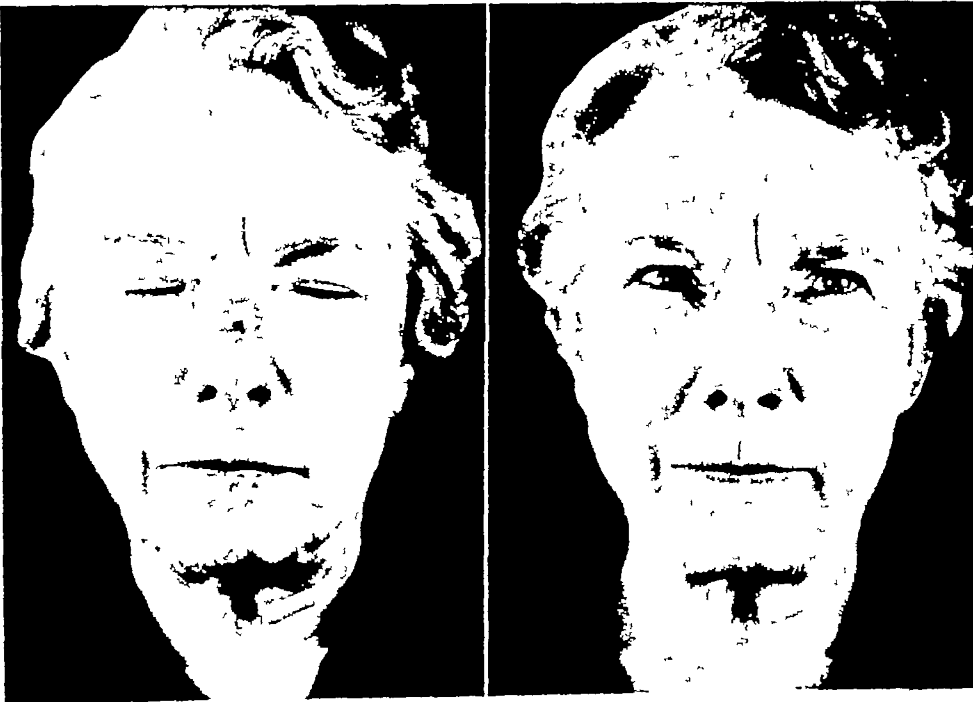


FIG 246 Recurrent basal-cell carcinoma of the nose with surrounding radiodermatitis The growth was still not attached to the underlying nasal bones and cartilages, so it was possible to excise it and do immediate repair with a full-thickness skin graft in one operation.

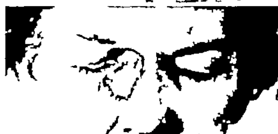




FIG 247 (*Top*) Basal cell carcinoma of inner canthus, creeping along the nose and back into the upper eyelid (*Center and bottom*) Result of wide excision and coverage of the defect with free skin graft from the clavicular region for softness and best match The sutures shown in the center picture were originally left long and used in a "tie-over" dressing

and the latter area can be covered with a split graft temporarily to keep it clean and healed

Large cancers about the face and the mouth may require the excision of features and present reconstruction problems that are covered in other chapters of this book For instance a small movable cancer of the nose may be excised and the wound closed by undermining and suturing A slightly larger movable skin cancer of the nose might be excised and the defect closed with a full thickness graft (Fig 246) However if such a lesion were over the cartilaginous portion and adherent to the cartilage but not to the lining, it would be excised en bloc with the cartilage, and the defect filled in with a flat composite graft from the back of the ear consisting of a layer of cartilage and external skin (Fig 104) If the lesion were in the ala and involved the full thickness, a full thickness excision would be done and for repair a complete composite graft would be used consisting of cartilage with skin on both sides (Fig 96) Larger fixed lesions of the nose might require full thickness resection and repair with an adjacent rotated cheek flap Very large lesions might require complete excision of the nose and total nasal reconstruction with a forehead flap All of these procedures are outlined in Chapter 24 "Repairs of the Nose"

In dealing with a large cancer any place on the surface of the body it may be best to cover the operative defect temporarily with a split-skin graft, when a satisfactory bed can be obtained and then substitute other covering later if there proves to be need for a change Split grafts are so easy to do and will take in so many difficult situations that they are invaluable for this purpose For instance in cancers over the side of the head, it may be necessary to chisel off the mastoid process or the outer table of the skull, or part of the mandible because of bony fixation to the tumor The removal is done in one piece and the bony portion of the defect is covered with a local flap of fat or muscle if possible, if not, cortical bone may be removed until all of the exposed bone is cancellous and bleeding and then a large split graft may be draped over the entire operative defect and packed in place with a good take usually resulting (Fig 248)

LYMPHANGIOMAS

There is still some question as to whether lymphangiomas are true tumors or congenital anomalies, but they do slowly increase in size and may become horribly disfiguring when present in the face. They are rather insensitive to radiation and the surgical



FIG 248 (*Left*) Extensive basal cell carcinoma, with long history of treatment with acids, electrocautery and radiation Fixed to the zygomatic arch and the mastoid process but not to the calvarium Widely excised in one piece, including the zygomatic arch and the mastoid process, as well as the ear fragments Split graft packed over defect (including cancellous bone areas) with result shown at right 1 year later Now 5 years without recurrence



FIG. 249 Excision of deforming lymphangioma of the forehead Skin involved down to the eyebrow, with subcutaneous tumor extending down into the upper lid The eyebrow was sutured back into position after excision, and the forehead was covered with thick split graft One operation.



FIG 250 Excision of deforming lymphangioma of the nose and immediate repair with a free full thickness skin graft from the supraclavicular region

treatment leaves much to be desired They are rarely malignant so that it is possible to do multiple partial excisions as the child grows, if the facial nerve or features can be preserved in that way Subcutaneous removal can be done if the skin is not too warty or pigmented but the skin is usually stretched so badly that much of it has to be excised anyway to effect a smooth closure At times the skin is so ugly and the lesion is so large that it is best to excise the whole thing in one block and cover the area with a flap or a graft depending upon the contour and the composition of the remaining base (Figs 249 and 250)

ARTERIAL HEMANGIOMAS

These are the bright red, rapidly growing hemangiomas seen in infants They are given the name "arterial" because of their bright red color though they are composed largely of neoplastic cylinders of solid endothelial cells which penetrate surrounding tissues and later canalize to form capillarylike vessels

They vary a great deal in their rate of growth and many or most of them begin spontaneous regression somewhere between the ages of 6 and 18 months or a little later Some are very slow growing and benign so that they grow a little, remain stationary a



FIG 251 Large, benign, verrucous growth of the scalp excised and the wound covered with split-skin graft in one operation

few months, and then gradually disappear without treatment Others grow with extreme rapidity, invade any tissue on all sides, and outgrow blood supply to the surface so that extensive ulceration may take place, with later infection and septic emboli These latter may destroy features or even life in some instances

For those which grow rapidly or endanger features, there should be no hesitancy in employing immediate effective therapy If surgical excision is done, it should be relatively wide because of their invasive tendency, and closure effected by shifting local tissues or by skin grafting Often, about the face, it is best to stop the growth with a very light dose of interstitial radon seed and then await spontaneous involution If there has not been ulceration, or if too much skin has been destroyed, a good repair may require resurfacing with skin grafts (Fig 252)

Some of the worst results have been in lesions which started out about 1 cm in diameter, and when they could easily have been controlled, the parents were advised to leave them alone Some of these have grown to cover the whole side of the face and slough out important features Although they finally underwent spontaneous regression, the residual deformities were very great



FIG 252 (*Left*) Rapidly growing, ulcerating hemangioma in young infant Controlled after this by implantation of a light dose of radon seed Later, unsightly skin was excised, and the area was resurfaced with a single split graft with the result shown at the right

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Restoration of Defects from Farm, Traffic and Industrial Injuries

GENERAL METHODS

Accidents from these sources account for a large percentage of trauma cared for on a plastic surgical service The various types of injuries and their repair are recounted throughout this book under various procedures burns electrical burns, military plastic surgery hand repairs foot repairs, penoscrotal repairs, and other regional chapters Some additional specific injuries and their repairs will be considered here

This chapter is not concerned with ordinary lacerations or contusions of the skin or with injuries to deeper structures but with the restoration of surface coverage when soft tissue flaps have been torn loose or completely out.

Early, solid skin healing is particularly essential when underlying fractures or tendon or nerve injuries are present In fact any direct fixation of fractures or tendon or nerve sutures should be delayed unless the surgeon is fairly certain that prompt surface healing can be obtained Free grafts do not provide a thick enough surface pad for this work, and there is always some uncertainty about distant flap coverage especially when direct ones are used

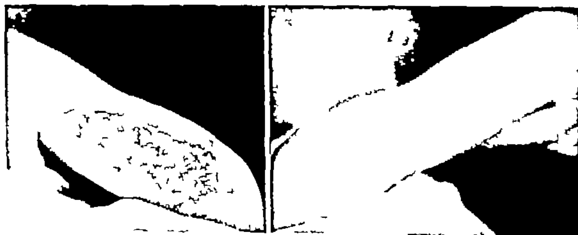


FIG 253 Typical wringer injury first seen 3 weeks after the accident The remainder of the dead *skin flap* was removed, and the wound was prepared for grafting As soon as the fine granulations shown were obtained, the wound was covered with a thick split skin graft.

When soft tissue has been scooped out and lost, coverage may be restored by readjustment of local tissues, a free split graft or a pedicle flap The exact plan will depend upon the contour of the wound and the deeper structures exposed, as well as the size of the wound Small wounds can frequently be closed by undermining the edges, sliding in tissue from one or both sides, and suturing Larger ones can be covered with a split graft if bare bone, tendons or nerves are not exposed, with the provision that it may be advisable to replace the split graft later with a flap if there is much depression or irregularity of the surface contour Exposed nerves sometimes can be transplanted under adjoining soft tissues and the above plan carried out Occasionally, it is possible to switch small flaps of fat from the edges of the wound and cover small areas of bare bone or tendon, after which the whole wound can be covered with a split graft If this cannot be done, one can consider the possibility of switching a direct, double-ended flap from the edge of the wound over it and immediately grafting the original bed of the flap The last course is to attach a direct flap from a distant source This requires, of course, that a flap be designed which can be brought into immediate contact with the wound and that the pedicle be at least as wide as the flap is long In general, it is best to rely on temporary split-graft coverage when at all possible and to bring the flap in as a later secondary procedure

When a flap is torn loose but not completely detached, every effort should be made to determine how much of it is probably viable, to save this portion and to cover the rest of the wound as indicated above In this connection, trap-door flaps (ones which are torn loose on three sides with a remaining attached pedicle on the fourth side) tend to shrivel and in so doing may collapse some of the intrinsic venous return Their circulation may actually improve after the flap is stretched out to original size and shape by suturing it back in its bed The circulation may be aided further by applying a pressure dressing over the flap to prevent stagnation of blood within it If such a flap is small and apparently not viable, one may consider removing it, trimming all the fat off and replacing the skin as a free graft, usually with a stent-type fixation

Some patients will be seen who need bone grafts, tendon or nerve work, whose wounds have healed by granulation and scar. In nearly all such instances, it is best to excise the scar throughout its entire depth and area until a perfectly soft bed is obtained and then cover the area with a pedicle flap The most common sites are in the leg, where the flap is usually obtained from the opposite thigh, and the forearm, where a direct flap from the abdominal wall is commonly used (cf Chap 33, "Skin Grafting in Military Plastic Surgery")

WRINGER INJURIES

These crushing injuries are most commonly seen in the upper extremities of children and are apt to be deceptively benign in their initial appearance (Fig 253) There may be wide areas of separation of the skin from the subcutaneous fat (and its blood supply) with only a little bruising apparent In addition, one or more flaps (often retrograde) may be torn loose

The initial appearance may not be very bad, but there is little reason for optimism here If hematomas or fluid collects in the planes of subcutaneous separation, and if the flaps become edematous with poor venous return, there may be widespread loss within a few days Therefore, treatment consists of trying to prevent these sequelae The areas of subcutaneous separation are carefully examined and palpated, any blood or fluid collections aspirated or drained, and massive firm pressure dressings applied with immobilization and elevation of the extremity and immobilization of the patient The prognosis can be determined best after 3 or 4 days of such treatment.

If flaps are torn loose and hanging they may present the appearance of questionable or possible viability on the initial examination However, they are badly contused and die more often than not Perhaps active bleeding from the edges is the only certain sign of viability in such flaps If the edges are washed with a wet sponge and do not bleed, it is usually best to trim them back until there is active bleeding suture this portion of the flap (if any) back in place, and split graft the remaining defect

At times the wrist will catch in a wringer, and the roller will continue to grind on the palmar surface until there is heat destruction of the bones and grinding away of the radial and the ulnar arteries as well as the median and the ulnar nerves. In some such instances, only amputation can be done because of a lack of the blood supply

Fractures are rare in these patients, so that if clinical examination shows no evidence of them it may be best to go ahead with definitive surgical treatment of the soft

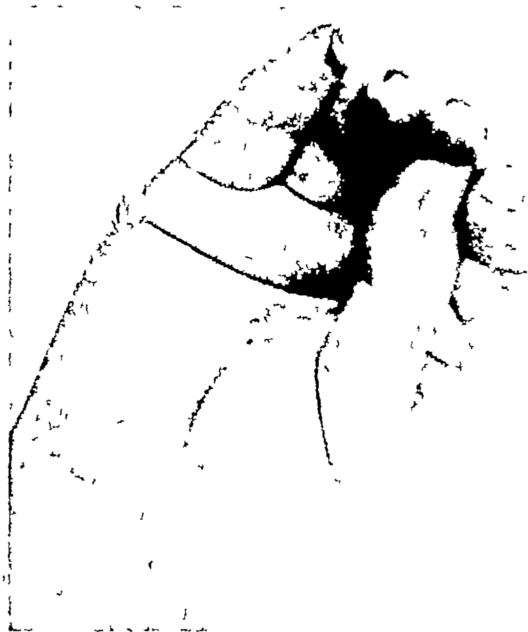


Fig 254 Mangle burn in child (*Top*) A very clean granulating wound following 2 weeks of excellent care by a local physician as usual, burned and dead epicondyles are exposed These were removed and the area was covered with two split grafts in one operation (*Bottom*) Early result shown 4 weeks later



FIG 255 Palmar half of 3 fingers sliced off in leather-sciving machine, going right down through the middle of the bones After thorough washing and irrigating of the wounds, exposed cancellous bone was covered with small fat flaps from the sides of the fingers, and split-skin grafts were applied The flexor tendons were gone, and the fingers were stiff, but the patient returned to his former job 2 months later and has continued to work at it for several years The hand is still useful for manipulating and steadying the leather as it goes into the machine





parts and obtain x-ray pictures after the pressure bandages are in place, rather than waiting for them and allowing further damaging changes to take place in the soft tissues

MANGLE INJURIES

These injuries may occur in home laundries (Fig 254), or commercial laundries, the latter often being worse because of the greater size and power of the machinery

The burn is usually the worst component of a mangle injury, though there may be some crushing and finger fractures (especially in the commercial variety), and there may be some grinding wringer effect at the upper limit of the injury (e g, near the axilla) if the patient could not get loose right away There may be dead bone in areas of bony prominence, such as the epicondyles of the humerus, the head and the olecranon process of the ulna, etc Sometimes finger fractures can be stabilized with Kirschner wires, and often burned bony prominences can be chiseled off after 1 or 2 weeks Other than this, the treatment is that of any deep extensive burn of the hand and the upper extremity

GENITAL AVULSIONS

These are described in Chapter 19.

AVULSED SCALPS

These are usually seen in women whose long hair has been caught in revolving machinery If the scalp is still attached to the head, the usual tests for flap viability should be made, and any viable portion sutured back down in place Even questionable flaps may be sutured back, replacing any lost areas later with split grafts However, if the scalp is torn completely off the head, it is best to discard it, resurface the head immediately with split grafts and have the patient wear a wig afterward (Fig 226) There are isolated reports in the literature of shaving these detached scalps removing the fat from the undersurface and sewing them on as free grafts In such instances, most of the graft is usually lost the portion that takes rarely grows any useful hair, the patient wears a wig anyway, and the convalescence may be prolonged over many months

HAND INJURIES

Flaps torn completely off of hands commonly expose wide areas of tendons and in such instances it may be best immediately to bury such a hand in an abdominal pocket When skin is sliced off without the exposure of tendons, immediate coverage with split grafts can be done This was done in one instance in a patient who sliced off the palmar half of all his fingers in a leather sciving machine The sciving knife split the phalanges leaving cancellous bone exposed almost the entire length of the fingers There is almost no padding on the palmar surfaces of the fingers, and they are motionless (due to loss of the flexor tendons), but the patient returned to work at his old job 2 months after the injury (Fig 255)

SLICED-OFF FINGERTIPS

Fingertips may be sliced off in bread slicing machines meat-slicing machines etc and brought in with the patient The separated fragment is usually not very large and is cleanly cut without much contusion If the fragment is no more than 1 cm in its smallest diameter, it may be sutured back on the finger and usually will grow in the same manner as a composite graft

The raw fingertip is covered with a small saline sponge the hand thoroughly washed with soap and water, and sterile drapes applied, here as elsewhere, it is best to prevent soap or any detergent from entering a raw wound to which a graft is being applied immediately

The separate fragment is washed with a saline sponge, and after hemostasis of the stump is obtained it is sutured in place with long interrupted No 000 black silk sutures which are then tied together over a pad of grease gauze and surgical waste to exert pressure on the graft The finger is immobilized on a small splint an over all pressure dressing is wrapped over the hand, and the hand and the forearm are kept elevated in a sling Antibiotics are given for a few days and all of the usual precautions and technics of free grafts to the hand are employed

If the separate fragment is more than 1 cm in length, some fat *may be trimmed* off the undersurface to bring it down to this size before applying it If there is a tiny piece of bone in it this is removed

If the fragment is not covered with grease oil or other *irritating materials, and* if it is not too large (e.g not farther back than the middle *of the nail), and if it is* not badly contused usually it *will take* satisfactorily and result in the best possible repair

PUNCH PRESS INJURIES OF THE HAND

These injuries are severe crushes *which* come in with portions of the fingers already gone or so severely mangled that amputation is necessary The loose fragments cannot be sutured back into place

The *main* consideration here is whether to preserve as much length as possible and this is important in some patients The ordinary procedure, of course, is to resect additional bone until the soft tissues can be

brought together over the end, or until a palmar flap can be brought clear over the end to the dorsum, this frequently means amputation back to the next joint

In some patients, with certain occupations or hobbies, it may be worthwhile to preserve additional length This can be done in some instances by mobilizing little flaps of fat from underneath the skin edges, turning them out over the end of the bone, suturing them together with No 000 white silk and applying a free skin graft In a man, a soft supraclavicular graft provides excellent cover for a fingertip Coverage can also be obtained in some instances with a cross-finger flap (Fig 83)

CORNPICKER INJURIES TO HANDS AND ARMS

The clawing rotating teeth of a cornpicker can pull most of the skin, or most of the skin and other soft tissues off the hand, or the hand and the forearm The worst injuries occur when the farmer uses the other hand reflexly to try to free himself and ends up with both hands and forearms in the cornpicker (Figs 256 and 257)

If only the skin is torn off without exposure of tendons, or if viable flaps are left which can be used to cover the tendons, early coverage with split-skin grafts can be done

If tendons or other important deep structures are exposed, it may be best to clean the hand thoroughly and implant it under a direct abdominal flap In some instances, it may be necessary to implant the whole hand and forearm under such a flap.

The extent of these injuries varies so much that specific rules cannot be made, except that stable surface coverage and healing must be provided first, with grafts or flaps, whichever are required, and as quickly as possible.

Figure 256 shows an extreme case in which the right upper extremity was torn off near the shoulder, and the soft tissues were clawed off the left forearm, except for a narrow strip about 1 inch wide under the ulna containing the ulnar artery and nerve, there was a large amount of daylight showing through from the other side between the radius and the ulna, and parts of both of these bones were dead. However, since he was a young farmer with a family to support, it was thought best to make extreme efforts Dead bone was excised, and direct chest flaps were applied to both the volar surface and the dorsum of the forearm to provide complete coverage Later, bone grafts were put in by an orthopedic surgeon with good success and with about one third normal function resulting in the extremity. A pectoral motor was constructed on the other side, and a cineplastic arm and hand were fitted Although he still has many difficulties, the patient is able to feed himself, dress himself, run a tractor, do farm chores and support himself and family.

STREET BURNS AND DIRT TATTOOS

Street or friction burns are treated in the same manner as heat burns, special care being taken to scrub out any ground-in dirt or oil These burns are usually superficial, but any areas of full-thickness loss may be grafted if necessary

If dirt is allowed to heal in superficial street burns, permanent dirt tattoos will result Many of these can be treated secondarily by abrading off the superficial layers of skin with sandpaper or rotating wire brushes, or slicing the superficial layers off with a graft knife or a dermatome and treating them the same as a split-graft donor area

Deeper pigment that has been blown into the dermis or the subcutaneous tissues may require full-thickness excision, with closure by suturing or grafting

Deep friction burns behave the same as thermal burns and require débridement and grafting.



FIG 256 Cornpicker injury with right arm torn off, and left forearm badly damaged (*Left top*) Dorsal surface of forearm, with dead areas of radius and ulna exposed (*Left bottom*) Volar surface of forearm, the white area in the ulcer is not bone but daylight shining through from the other side (*Right*) Position following excision of dead bones leaving drainage on the volar side and attaching the dorsal side to a direct chest flap Later, the forearm was detached with surplus flap which was wrapped around to cover the volar defect

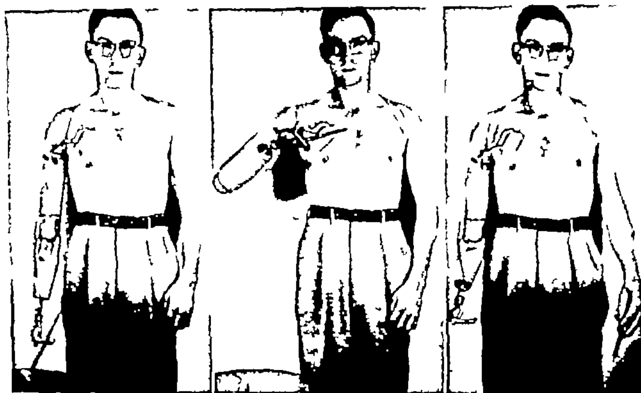


FIG 257 Same patient as in Figure 256 Early result shown after complete healing subsequent bone grafting by orthopedic surgeon and construction right pectoral cineplastic motor on our service The patient has good strength for gross movements in the left hand but little fine movement due to the fact that the median and the ulnar nerves are gone and most of the tendons have been torn out. Cineplastic arm used for fine movements. He dresses and feeds himself runs a tractor and all usual farm implements to earn a living again as a farmer



FIG 258 Commercial tattoos The one on the thigh has been excised and sutured The one on the forearm has been excised and covered with a full-thickness skin graft.

COMMERCIAL TATTOOS

Deliberate tattoos are usually quite deep in the dermis, or even somewhat in the subcutaneous tissues Some improvement can be obtained by sandpapering, or by secondary tattooing heavily with tannic acid to get peeling, or by cutting very thick split grafts from the involved skin Deeper and heavier ones will require surgical excision, with closure by suturing, local flaps or free skin grafts (Fig 258)

ROPE BURNS OF HANDS

If a rope or a cable is pulled through the hands at a fast rate, a deep burn of the palm and the flexor surface of the fingers may occur, consequently, a flexion contracture will be the result Early débridement and grafting are recommended as the best treatment, but if the patient is first seen after contracture has occurred, the scars may be excised and free grafts inserted (Fig. 259)

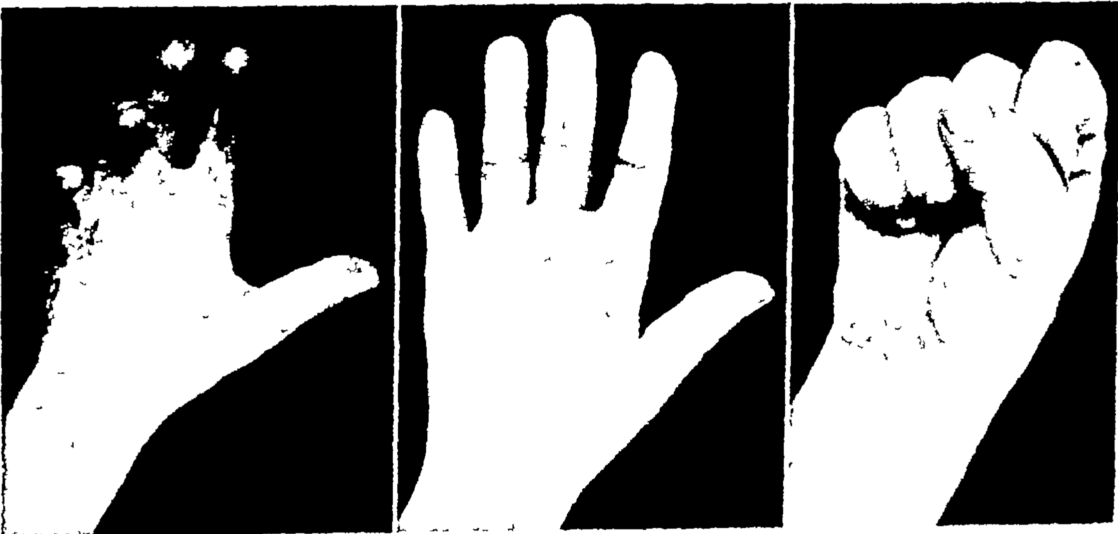


FIG 259 Rather typical rope burn of the hand with flexion contractures of the ring and the little fingers Repaired in one operation by excision of scar opening of contractures and covering resultant raw areas with free full-thickness skin grafts Complete function was obtained



FIG 260 Acid burns of the face Small, contracted keloided scars at the margins of the upper and the lower eyelids were excised and covered with skin grafts. The scar over the glabellar region was excised and resurfaced with a full thickness graft. These burns remained red for a long time, but had bleached out as shown 2 years later

CHEMICAL BURNS

Acid or caustic burns may be seen in chemical workers (*Figs. 260 261*) or others and immediate first-aid treatment should consist of copious washing of the areas with plain water, preferably in a shower bath or with a hose Phosphorus burns are an exception and are preferably treated with a weak solution of copper sulfate

After removal of the chemical they may be treated in the same manner as scalds or fire burns. Superficially burned areas will usually be healed within a few days but may remain red for a longer period than heat burns Deeper burns may be allowed to heal spontaneously or may be covered with split skin grafts according to their size and location. Scars from them seem to be more prone to keloid than scars from heat burns so that subsequent surgical excision and closure by suturing or grafting may more often be necessary

If there is any question of involvement of the eyes, an ophthalmologist should be in attendance and joint decisions should be made throughout the patient's course Lye burns commonly destroy the globe but may leave useful vision in some patients with adhesions between the globe and the lids. When possible it is best to release such adhesions by swinging adjacent flaps of conjunctiva across the dissected area The next best choice is a free graft of mucosa from the cheek lining and if it does not work one may be forced to use a split skin graft Any such skin grafts should be cut as thin as possible from almost hairless areas but even so they cause much discharge and inflammation in the conjunctival sac so that they are to be avoided whenever possible When used, it may be advisable to try to switch conjunctival flaps so that the globe and the central portion of the lid are covered with normal tissue and any skin graft used



FIG 261. Acid burns of the face and the nose A keloided scar over the tip of the nose and the left nostril was lumpy and irregular, so this was excised and resurfaced with a full-thickness graft from the supraclavicular region.

is placed as lining over the lateral or medial side of the lid where it will not rub on the cornea. The question of corneal grafting is left up to the ophthalmologist, of course, but if it is done and any useful vision is regained, it may be better to leave the eye in a partly fixed position than to risk putting a skin or mucosal graft in the conjunctival sac with it. When the eye is so badly damaged that removal is necessary, the conjunctiva is usually destroyed too necessitating restoration of lining before an artificial eye can be worn (Fig 187) Mucosal grafts shrink so much that it is almost impossible to line an entire socket with them split-skin grafts usually being necessary for this purpose Again the grafts are cut quite thin from a relatively hairless area, and the socket is dissected out to about twice the desired size before the graft is put in over a dental wax or gauze mold An artificial eye is fitted about 2 weeks later and should be kept in day and night for several months These sockets tend to be dry and there may be some sebum from the skin grafts creating a rather disagreeable situation The best solution though not perfect, seems to lie in frequent removal of the eye cleansing it and the socket and coating the eye with mineral oil or some other lubricant so that it will appear moist.

Burns of the mouth caused by lye or some other chemical, are seen occasionally In such instances the patency of the esophagus should be investigated The scars inside the mouth may involve the buccal mucosa and anterior pillar region so as to prevent opening the mouth General anesthesia in such patients always presents some hazards so that it may be best to do the work under local anesthesia The scars are opened up inside the mouth, and a jaw dilator is used until the mouth can be opened and blocked in that position Then the raw surface is covered with a thick split-skin graft put in over a dental wax mold The patient may be fed liquids from a cup with a spout or tube feeding may be used for a few days. If not too uncomfortable the mouth may be left blocked open for 3 or 4 weeks and some form of jaw dilator used daily for a few weeks after that to help counteract any tendency for it to close down again Usually it will contract down some after the initial weeks so that it may be advisable later to open through the center of the graft again and spread and insert another piece of skin graft Rarely, a patient will be seen who has so much dense scar in one cheek or side of the mouth that complete release by skin grafts seems to be doubtful In such instances one may raise a delayed flap on the same side of the neck with the pedicle just under the jaw and swing it up through the lower buccal fornix to line the cheek. However, one may always try the split-graft lining first and if it does not work it is never too late to resort to the flap which does give a more flexible lining with less shrinkage

Besides the above mentioned "false ankylosis" one may see adhesions between the gums and the lips or the cheeks between the tongue and the floor of the mouth or the hard palate or elsewhere in the mouth. These are usually released by dissection and covering the resultant raw areas with split skin grafts put in over stent molds

31

Repair of Electrical and Cathode-Ray Burns

GENERAL CONSIDERATIONS—ELECTRICAL BURNS

Electrical burns occur most commonly in linemen (Figs 14, 15) and in adventuresome older children from coming in contact with high tension lines First-aid treatment and early general care will not be discussed here except to say that early death is common from ventricular fibrillation, paralysis of the respiratory center, tetany of the respiratory muscles, or some combination of these factors Unconsciousness may persist for days, and late deaths may occur from acute atrophy of the liver, or from unexplained lesions, so that an internist should be in charge of the patient from the beginning.

The local burns are usually limited in area but quite deep so that tendons or even bones may slough out eventually The entry burns are commonly in the hands and may be more widespread and serious than the exit burns in the buttocks, the legs or the feet The latter may appear to be deep, charred puncture wounds but are actually more widespread than that, and wide and deep débridement may be necessary to get down and around to viable tissue

Damage to the vessels between the points of entrance and exit of the electric current may be severe enough to cause their thrombosis or spontaneous bleeding It is possible that damage to vessels may result from their being a pathway for the current This sometimes seems to be expressed in repeated hemorrhage and crumbling of the vessel wall in attempting hemostasis, so that great difficulty may be encountered in checking the flow from the damaged vessels

LOCAL CARE OF ELECTRICAL BURNS

If possible, the definitive repair is begun as soon as the patient is first seen, whenever his general condition permits The advantage of doing any surgical procedure in the operating room under adequate anesthesia is obvious, rather than trying extensive procedures in the emergency room

Primary excision and immediate coverage may be done in some areas if the exact extent of the burn is recognizable. There may be a tendency here to be too conservative, and the damage is apt to be more than one might think so that débridement should be a little more than appears to be adequate In these instances, initial repair usually may better be done by local closure or with a free graft, and any complicated flap coverage should be postponed

Free skin grafts can be used to secure a healed wound and often suffice for permanent coverage. If for temporary coverage, the wound is said to be *dressed in a graft*. Split grafts can be placed on bleeding bone and expected to grow. Small areas of exposed (but not burned) tendon can also be bridged over with this type of graft



FIG. 262 Deep electrical burn of the foot One operation for débridement and grafting with complete rehabilitation See text for details. (Brown and Fryer Ann Surg. 146 352-353)

Dressing the wounds after they have been cleansed and irrigated may be all that the patient s general condition will allow initially in some cases. The dressing should allow for surgical drainage be comfortable and splint the part. A firm grease gauze pressure dressing accomplishes this and subsequent dressings are done as necessary

Débridement of all nonvital tissue usually can be done then within a week or so after the injury The necrotic soft tissue should be excised surgically rather than waiting or relying on chemical débriding agents. Nonviable bone is rongeured away and sequestra are lifted out The wound is prepared for coverage with a graft or flap as soon as possible





FIG 263 Deep electrical burn of the foot extending into the ankle joint. Débrided and covered with split skin graft in one operation with permanent healing See text for details. (Brown and Fryer Plast. & Reconstruct Surg 18 177 184)



FIG 264 Other foot on patient in Figure 263 Deep electrical burn over malleolus débrided and covered with split graft in one operation, with permanent healing See text for details (Brown & Fryer Plast. & Reconstruct Surg 18 177-184)

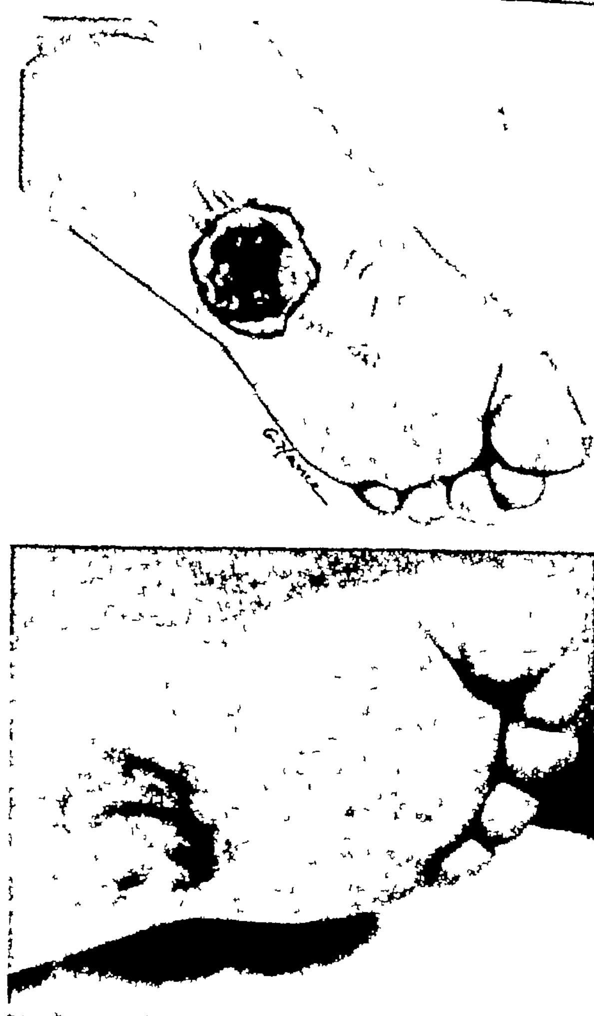


FIG 265 Bottom of left foot shown in Figure 263 Débridement and split-graft coverage in same operation. Two feet, three areas, one operation—permanent healing of all See text for details

Amputations are the reverse of reconstructive surgery, and the main effort should be to avoid them and save all possible tissue If there is a sustaining blood supply to an extremity, it is not removed without due consideration and usually only after giving it a chance for survival and thus a period of evaluation as to its possible final function

Permanent pedicle blood-carrying flaps are useful in many of these patients and have the advantage of bringing a new blood supply into a formerly relatively avascular area Delay of these flaps in some areas may not be necessary Subsequent deep grafts, as of bone or tendon, will survive in questionable areas because of this added vascular soft-tissue pocket The donor site for the flap can be covered with a free graft at the time of local rotation or subsequently

Short, broad-based, direct flat abdominal or chest flaps are used where thicker coverage than a free graft is required and where a sufficiently large local permanent pedicle flap is not available Time is saved and scarring in the flap is avoided by immediate transfer of this type of flap Scar in the recipient area is excised back to good minute blood supply, and the flap is applied accurately Usually the pedicle can be cut within 3 weeks, returned, and the remainder of the donor site covered with a split graft Bone grafts, joint, tendon or nerve operations can be done through the flap in 2 to 3 months time, or sooner if necessary This



Fig 266 Deep electrical burn of elbow area treated 2 years before elsewhere with pinch grafts. (*Top*) Heavy scar contracture breaking down repeatedly (*Center*) Result of permanent soft coverage with direct flap from lower chest. (*Bottom*) Position of flap application Two operations, on and off in about 18 days. See text for details (Brown & Fryer Plast. & Reconstruct Surg. 18 177 184)

is another instance where the deep repair can be no better than the surface coverage

Some facets of this work may be covered best by describing some of the repairs shown in the illustrations in this chapter

Figure 262 shows a patient who took in over 12 000 volts through his knee with the point of exit through the foot while on a pole Hanging by his safety belt, his head touched another wire He was taken to the ground by other workmen and remained unconscious for 24 hours After receiving emergency care in a local hospital he was transferred for definitive repair The wounds of the scalp the knee and the foot were débrided in the operating room and the wounds were dressed in split grafts He has required nothing further than this initial débridement and graft closure and has returned to his former occupation as a lineman Although débridement of his foot necessitated excision of necrotic plantar fascia, the free graft has proved to be durable enough to wear climbing irons

Figures 263 to 265 illustrate another example of débridement, dressing the wounds in free grafts with resultant adequate surface coverage for permanent function While at work at an electrical manufacturing plant, this patient's feet became entangled in a high voltage wire The drawings illustrate the conditions of the burns when he was first seen 1 month later, after amputation had been recommended elsewhere These wounds were débrided, in the ankle down to the viable bone and dressed in a split thickness graft. This patient is walking now with the assistance of a cane and more complicated coverage is not indicated

Figure 266 shows a deep burn of the arm

sustained 2 years previously by contact with high voltage at a power company substation Treatment at that time, elsewhere, is reported as consisting of sequestrectomy of the radius and pinch-graft coverage There was subsequent repeated breakdown of the resulting heavy scar contracture Excision of the thick scar necessitated flap coverage which was done with a direct short broad-pedicle abdominal flap, applied immediately to the defect The arm was detached from the abdomen 2 weeks later, and the defect left by the flap was covered with a thick split graft. Function has been restored



FIG 267 (*Top, left*) Deep electrical burn through the skull and the dura Necrotic skull removed through both tables, necrotic dura excised, and split-skin graft packed over defect (*Top, right*) Appearance some months later, with new bone grown in to edges marked A little later, a permanent pedicle flap was delayed on the occiput (*bottom, left*), shifted forward, and later rib bone grafts were inserted, with final result as shown at bottom, right See text for details (Brown & Fryer Ann Surg 146·342-353)

Figures 267 and 268 illustrate not only a successful scalp and skull repair but also the co-operation possible between the patient, the insurance carrier and the surgeon Contact with high voltage on a pole resulted in a deep burn of the head with necrosis of the overlying scalp, through both tables of the skull and involving the dura At the first operation when he was first seen 1 month after the accident, the burn was débrided with removal of full thickness of the skull and the dura The wound was dressed in a split-skin graft at this time A healed wound resulted and the patient wanted to return to work which he did with the permission of the insurance carrier Returning for examination 6 months later considerable spontaneous ingrowth of the skull margins was noted, as shown in the drawing in Figure 267 After 4 months of working at his former job the first stage delay of a local scalp flap was done and after a period of returning to work again, the permanent pedicle flap was rotated over to cover the defect The soft tissue pocket having been prepared, the bony defect was subsequently repaired with a bone graft from the ribs.



Fig 268 Drawing of rib bone grafts inserted to cover skull defect in patient in Figure 267

Figure 269 shows a lineman who took 7 200 volts between the hands and the head and was knocked from the pole to the ground 20 feet below He had a full-thickness loss through the scalp and one through the forehead, with a small opening into the frontal sinus. The first operation was a débridement and split-skin graft dressing"

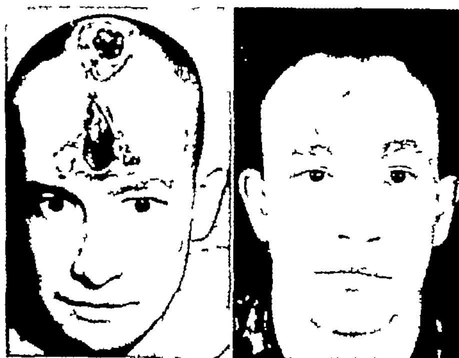


Fig 269 (*Left*) 7 200-volt electrical burn with full thickness loss in scalp and through forehead and skull into the frontal sinus 5 ground burns on lower extremities and one on hand (*Right*) Final result after débridement and split graft dressing of defect 6 weeks after accident and later advancement of scalp and adjustments (Brown & Fryer Ann Surg 146 342 353)



FIG 270 Electrical burn of the mouth in a child It was kept clean and covered with cold cream in the early stages and healed as shown in the center picture (*Right*) Final result after excision of skin scar at the angle of the mouth and application of small, full-thickness graft, and after detaching adhesions between the gum and the lip in the inside and relining the lip with a flap of mucosa swung in from cheek

of the wounds 6 weeks after the accident The free skin grafts took completely, even bridging the small hole into the frontal sinus Later, additional work was done to advance scalp flaps and excise some of the scalp graft The patient is well, except for a cataract which is developing in one eye

These patients illustrate in general how most of these repairs can be done expeditiously and permanently with free skin grafts in one or two operations, or the occasional patient who requires flap coverage can get it in one or two more operations but rarely is there any reason to embark on an involved or prolonged series of operations

ELECTRICAL BURNS OF THE MOUTH

Electrical burns of the mouth may occur in small babies from sucking on electrical plugs or cords on the floor (Figs. 270, 271 and 272) The feeding problem may become rather acute so that it is best to hospitalize many of these babies and give them supplementary parenteral fluids as necessary They



FIG 271. Electrical burn of mouth, some months afterward (*left*) with marked contracture (*Center and right*) Result of opening, switching small flaps of mucosa out for vermilion, and small full-thickness grafts on the outer surface of the lips

can be fed from an Asepto syringe with a short length of rubber tubing on the end, if the nurses are persistent and patient enough The burned areas should be kept clean and free of crusts and coated with a thin layer of petrolatum until healed, and no surgery is done until some months later

Many rather extensive burns heal with surprisingly little deformity (Fig 270), so that the required secondary work is much less than was surmised at first. However the extreme burns will heal with marked purse-string contracture of the mouth opening (Fig 271), necessitating subsequent surgical separation of the lips with resurfacing of the vermilion by flaps of oral mucosa swung outward and sometimes restoration of lining in the buccal and labial fornices with split skin grafts

If there has been extreme loss it may even be necessary to switch flaps early in the repair and then finish with mucosal adjustments and free skin grafts (Fig 272)

CATHODE-RAY BURNS

As industry uses various new rays for determination of the purity of solids or for investigations of plastics and metals and other new uses human errors will occur with accidental exposures and resultant damage to some of the workers even up to the status of highly educated and indoctrinated research investigators.

Cathode ray machines for these investigations with heavy beams of electrons coming out of them may not give the usual electrical current burn but there is a stream of electrons on the move, which has come from an electrical current and is electrical in nature These rays have burned patients accidentally, with severe results

In the first of these patients observed on



Fig 272 (*Left*) Extensive electrical destruction of face, lips and buccal mucosa. Basic operations through 13 year period by Dr Robert H Ivy with pedicle flaps (*Right*) In following 7 year period, 16 operations for release of fornix contracture construction of simulated vermilion and development of contour anatomy as close to normal as available tissue permits. Restoration of satisfactory usefulness and of the main function of the face that of looking normal This patient is studying medicine (Brown & Fryer Ann. Surg 146 342-353)











FIG 273. Cathode-ray burn of hand (*Top, left*) Blistering that first developed 2 weeks after exposure (*Top, right*) Breakdown 4 days later (*Center, left*) Healing progressing 6 days later (*Center, right*) Almost healed 1 month later (*Bottom*) Final appearance several months later Skin grafting throughout the area may be needed later if secondary breakdown occurs. (Brown & Fryer: Ann Surg 146:342-353)

our service (Fig 273), there was a feeling of slight heat while the exposure was going on during only a few seconds but the exact amount of electron current could not be de termined The patient showed only a little irritation of the skin of the hand for 2 weeks and then went on to extensive blistering and some full thickness loss in the next month followed later by epithelial ingrowth and spontaneous healing It is not certain yet whether or not he will require skin graft replacement later

Another patient did not show blistering until 4 weeks after the burn, but then showed a still worse reaction than an associate worker with the same exposure

One patient, unfortunately looked into one of these machines while it was on and received some erythema over the face, but so far has not developed cataract

It is possible that the effects here are somewhat the same as recently reported in a case of "radar beam burn" which has raised the question as to what safeguards, if any are necessary in the use of radar ranges, etc.

The use of cathode-ray machines is too recent for any considerable experience with human burns, but perhaps the main thing at present is to be careful of an optimistic prognosis, at least until a few months have elapsed

32

Surgical Repair of Radiation Injuries and Atomic Burns

Excessive exposure to x-rays produces certain changes in the skin and other tissues that sometimes require excision and repair Radium and other radioactive substances may also cause severe changes, and atomic warfare may produce lesions similar to those seen in local areas at present The skins of some individuals may be unusually sensitive to the rays, with acute episodes that may clear up in time, but permanent chronic changes develop in practically all skins in which there has been heavy or repeated excessive exposure or mistaken dosage

The above comments have no relation to the usefulness of, or the indications for x-ray therapy, nor are they meant to suggest any directional approach to the problems in the use of irradiation

SOURCES OF INJURY

Burned hands in physicians are the most frequent examples of radiation injury seen at the present time (Fig 275) Many of these occur while the doctor is reducing difficult fractures under the fluoroscope when his anxiety for the welfare of his patient has dulled his regard for his own personal safety Nevertheless, these are preventable, and every physican using radiation equipment should be aware of the effects of a single large dose and of the irreversible, cumulative effect of repeated small doses over many years

The list of early workers with radiation who have been burned is long, and contains many names well known to the profession Dr Walter Cannon, late professor of physiology at Harvard, suffered burns of his hands that required excision and grafting These resulted from exposure while doing his pioneer work on roentgen studies of the gastro-intestinal system, before the late effects on the skin were known

Dentist's fingers are sometimes burned (Fig 276) especially when they hold films in patient's mouths during exposure.

Prolonged fluoroscopic examinations have produced some of the most unfortunate burns, with miscalculations in distance, time or filters probably responsible (Figs. 274, 289, 290 and 292). Examinations of empyema fluid levels, fractured metatarsals and fractured vertebrae have resulted in especially bad ones. These are such a great trouble to the patients and to those responsible for them that it seems advisable to make warning mention of this source.

Acne, eczema, port-wine stains, plantar warts, epidermophytosis and pruritus ani are all troublesome diseases but are as nothing compared with the possible effects of excessive radiation therapy on them (Figs 277, 281, 282, 285, 287, 288, 177 and 178)

"Sailor's skin" or "farmer's skin"—the dry, atrophic, teleangiectatic skin resulting from decades of heavy exposure to sunlight—is especially intolerant to irradiation

The pathologic changes in this type of skin are similar to those in a mild x ray burn and it is probably advisable to treat keratoses, skin cancers and even lip cancers by other means in such patients

Commercial epilation of superfluous hair by use of x rays has caused some of the most dramatic, extensive and useless burns (Figs. 278 and 291) Patients have been seen with burns of the entire lower legs the outside of the thighs the axillae outside of upper arms entire forearms hands back of neck entire face and entire front of neck from such treatments The prolonged morbidity suffering and loss of economic and social status endured by these patients have no possible justification in relation to the slightness of their original complaint of superfluous hair and this commercial procedure cannot be condemned too severely

As more time elapses for everyone to see the distant effects of radiation treatment perhaps changes in therapy or dosage will



FIG 274 Fluoroscopic burn following exposure for locating foreign body Complete early resection and immediate repair with split graft. One operation with normal function resulting





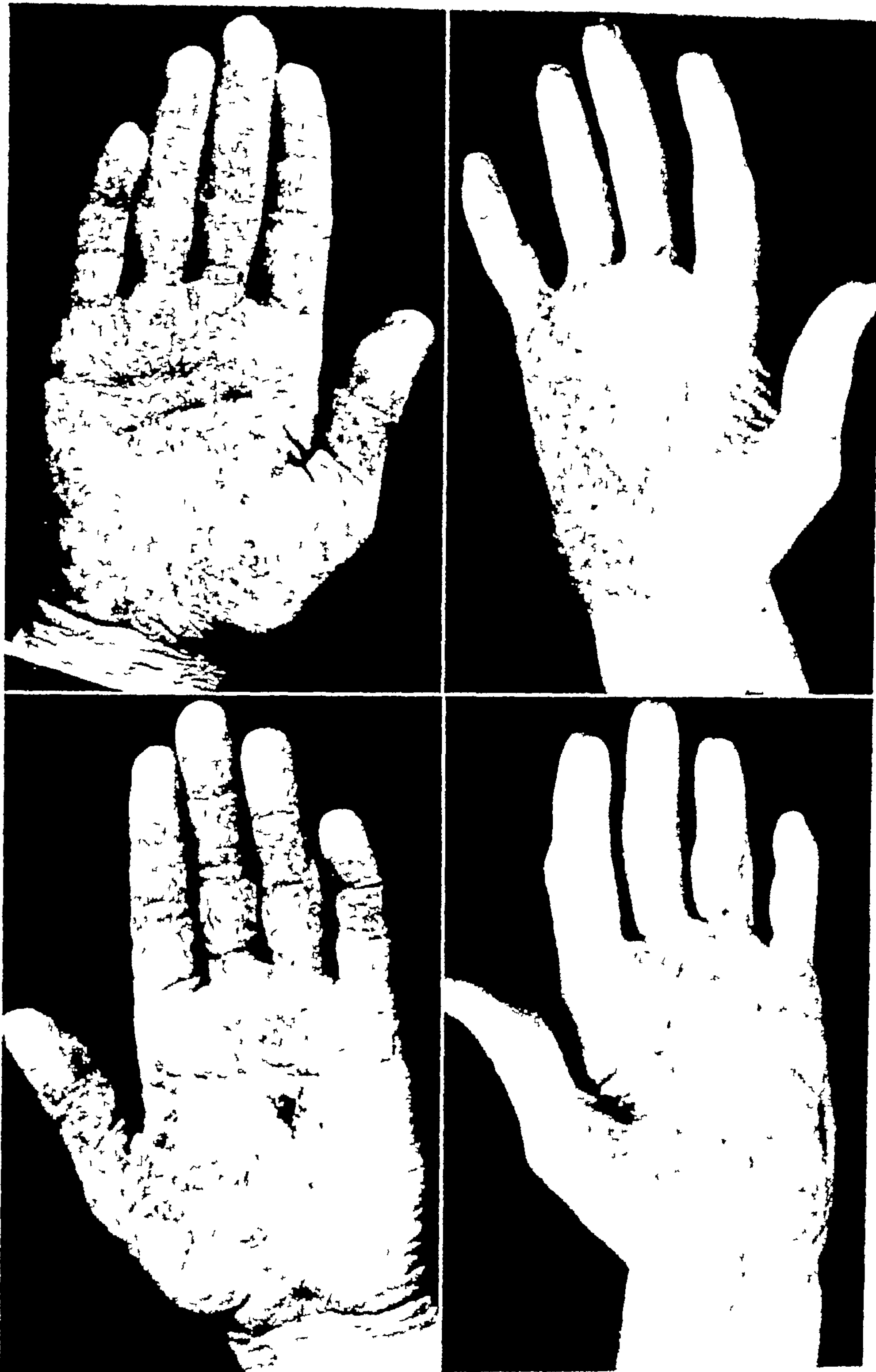


FIG 277. Eczema burn Wide deep burns of both hands from treatment for eczema. Repair by resection and replacement of most of the skin of both palmar surfaces, including the fingers Two operations Function about normal.



FIG 278 Commercial hair remover burn Excessive burning from commercial x ray treatment to get rid of hair The patient had arms, axillas and legs com pletely burned Treatment by excision, in two stages of all skin of the lower arm and immediate split grafting



FIG 279 (*Top left*) Shows endarteritis and endophlebitis at the junction of the skin and the subcutaneous tissue with complete occlu sion of venule and almost of arteriole Loss of skin appendages. (*Bottom left*) Telangiectasis of subepithelial capillaries probably as the re- sult of obliterative changes of venules draining the skin. (*Bottom right*) Typical coal spot. Dilated thrombosed telangiectasis with surface epithelium beginning to grow down around it to cast it out Hyperkeratosis over the area These are the first 3 consecutive stages of a radiation burn of the skin.



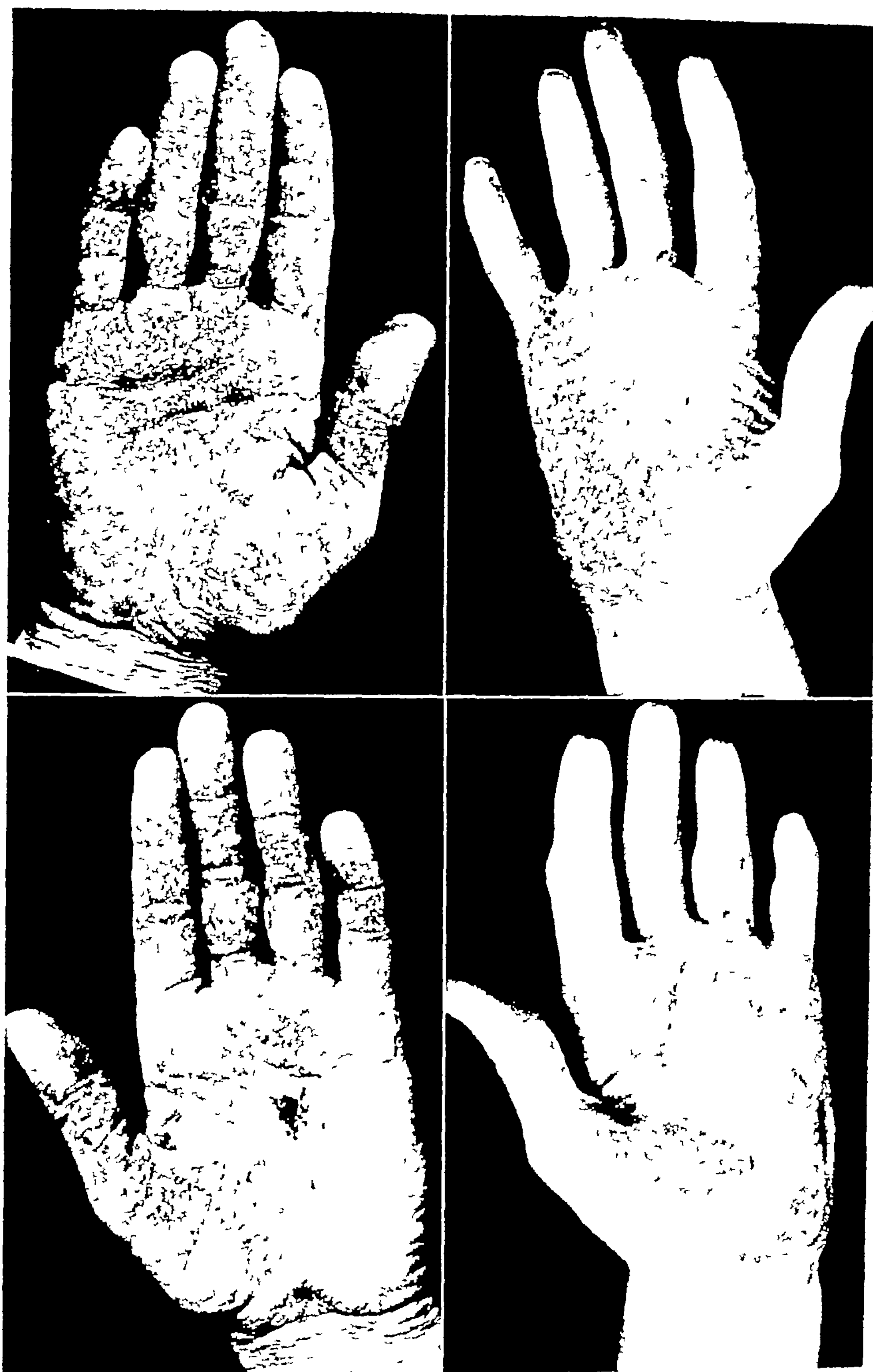


FIG 277 Eczema burn Wide deep burns of both hands from treatment for eczema Repair by resection and replacement of most of the skin of both palmar surfaces, including the fingers Two operations Function about normal



FIG 278 Commercial hair remover burn Excessive burning from commercial x-ray treatment to get rid of hair The patient had arms axillas and legs completely burned. Treatment by excision, in two stages of all skin of the lower arm and immediate split grafting



FIG 279 (*Top, left*) Shows endarteritis and endophlebitis at the junction of the skin and the subcutaneous tissue with complete occlusion of venule and almost of arteriole Loss of skin appendages (*Bottom left*) Telangiectasis of subepithelial capillaries, probably as the result of obliterative changes of venules draining the skin (*Bottom right*) Typical coal spot." Dilated thrombosed telangiectasis with surface epithelium beginning to grow down around it to cast it out Hyperkeratosis over the area These are the first 3 consecutive stages of a radiation burn of the skin.

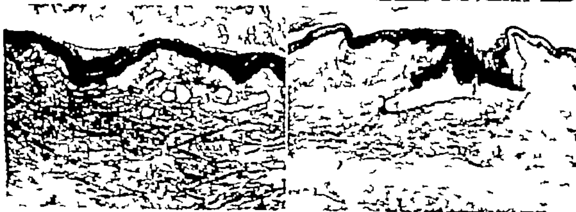




FIG 280 (*Top*) Casting off of numerous "coal spots." The epithelium is shown actively growing "under coal spots" (clotted vessels) in the process of casting them off Excessive hyperkeratosis probably as a product of the short life cycle of the cells, which may be brought about by the continual and excessive wound stimulus of the "foreign bodies" in the dermis In the upper left can be seen clotted vessels in the keratin that have already been cast out (*Bottom*) Development of carcinoma from the continual wound stimulus The epithelium apparently finally invading in general instead of purposefully, to get rid of "coal spots" These are the last 2 stages of radiation burns of the skin

these dilated capillaries is followed by thromboses, which later become organized and in the process may rupture the vessel walls with some leakage of blood cells out into the subepithelial spaces These black "coal spots" are grossly visible and are usually several millimeters in diameter

It is well known that the dermis is intolerant of macroscopic foreign bodies (e g , fine silk sutures will remain indefinitely in the subcutaneous tissues but are always cast out of the dermis)

Thus the development of carcinoma in radiation lesions may be about the closest that we have come clinically to the actual knowledge of the formation of carcinoma The epithelium is continually stimulated (Fig 279) to downward growth for so many years to cast off the recurring "coal spots" and to heal the recurring ulcerations that it finally loses the normal growth response (to these foreign-body and wound stimuli) and goes on into malignant change (Fig 280).

The clinical stages of atrophy, telangiectasis, "coal spots," keratosis and carcinoma are typical for chronic burns, such as those found on physician's hands, or when repeated treatments have been given, as for acne, goiter or excessive hair. The progress of the stages is different for different patients and different exposures, but generally there is telangiectasis in from 3 to 10 years · "coal spots" and keratosis in from 10 to 15 years, and carcinoma in from 20 to 25 years Malignant change has been noted as early as 3 years, however

An interesting thing is that in the donor site from which a split graft is taken to



FIG 281 Widespread involvement following treatment of acne. As usual the tip of the nose, since it was closest to the tube was burned the worst Repair was made by resection and immediate split grafting Four operations were performed, for both cheeks, the whole nose and the upper lip



FIG 282 Early occurrence of a burn following radium treatment of a hemangioma Repair was made by excision and full thickness graft from the clavicular region One operation



Fig 283. Radiation lesion of the neck, repaired with split-skin graft in one operation

repair an x-ray burn, the opposite reaction takes place in that the deep epithelial cells de-differentiate to re-cover the bare surface that is left when the skin is split in two

The carcinomas that develop in radiation burns are usually squamous-cell in type, though occasional basal-cell or basal-squamous lesions are seen The squamous-cell lesions can and do metastasize, while the basal-cell lesions often show "rodent ulcer" characteristics with deep local invasion

As a rule, x-ray burns are heavily contaminated with a wide variety of virulent bacteria This is partly due to the many tiny crypts and recesses afforded by keratoses, recurrent ulcerations and cast-off "coal spots" and partly to the cessation of sweat-gland and sebaceous activity, with loss of the normal skin-cleaning mechanism The lesions may be so painful that they are left grossly dirty because the patients simply cannot tolerate the added pain of cleaning the wounds This is an important factor in the consideration of any surgical treatment and was responsible for some grave wound infections before the days of



Fig. 284. Atrophy and deformity following radon treatment of a hemangioma Excision and repair was cross-lip flap. Two operations



FIG 285 Eczema burn Extreme involvement with malignant loss of the nose and the chin and with multiple carcinomas throughout the areas Repair was accomplished by complete excision and immediate *free grafting*. Four operations. The prosthetic acrylic nose was made by Miss Gertrude Hance

effective chemotherapy A corollary to this is that these wounds and areas will not tolerate the local application of strong antiseptics

TREATMENT OF ACUTE BURNS

Acute burns are usually the result of a single massive dose often *with inadequate* or no filtration They are most commonly sustained in fluoroscopy either in doctor s hands (Fig 275) or in patients who have had elusive foreign bodies buried in the tissue

Even in doctors the true nature of such burns is sometimes not apparent and they may be mistakenly treated as a severe allergic condition or as a dermatitis medica*mentosa* These areas are apt to be markedly swollen and edematous reddened weeping serum and characterized by excruciating deep-boring, throbbing pain They typically become worse each day for 1 or 2 weeks and seem to be refractory toward all treatment In the worst cases the skin may turn white after a few days (as in a deep fire burn) and then slough, leaving a foul, greenish gray sloughing ulcer In the milder ones, the redness swelling and pain gradually subside and for a few months, at least, the skin appears fairly to be normal

The pain in acute burns may be so severe as to require hospitalization and heavy sedation One patient required 6 grains of morphine a day and the tendency toward addiction deserves to be regarded with caution.

As some areas that are acutely burned do recover or at least serve as adequate covering for the part and as there is not much chance of determining the extent of damage of an acute burn very early operation is seldom indicated

Local anesthetics are usually unavailing



FIG 286 Malignant breakdown of an old x-ray burn in an area treated for tuberculosis of the lymph nodes Wide, deep resection of the carcinoma (done by Dr Bradford Cannon) and secondary repair with a thick split graft Two operations

and may add a secondary drug dermatitis The use of aloe vera (an antipruritic which was formerly used for a variety of skin conditions) has been suggested and, if obtainable, may relieve itching and some pain to a worthwhile degree However, getting it fresh and keeping the bulky split leaf in place is a task that few patients will carry out very long

These areas are less painful if they are sealed off from the air by some bland ointment (e g , cold cream or lanolin, *not autoclaved*) and a loose, soft cotton dressing without any gauze next to the skin Elevation and immobilization of the hands may be quite helpful Strong antiseptics, especially those containing heavy metals, are to be avoided Gentleness, cleanliness and the avoidance of irritants are the fundamentals of good local treatment

The use of ultraviolet or further radiation of any kind is definitely not advisable and is mentioned here only because it has been recommended There does not seem to be any justification for further radiation therapy in an effort to relieve this disease, which is already the result of too much irradiation

If the burn has been from a single cauterizing dose in which the limits are fairly well defined and ulceration seems likely with little chance of proper healing, early excision and grafting may be worth trying. In this instance, the depth of the trouble may not be apparent, and there may be difficulty with a free skin graft

TREATMENT OF CHRONIC BURNS

The diagnosis is often missed because the patient may be unaware of the cause of his condition. This is true even in the cases of some physicians who do not associate the chronic dermatitis of their hands with the holding of a fluoroscopic screen for a few



FIG 287 Acne burn. Widespread burn in a doctor following treatment for acne The results of resection and immediate free graft after 2 weeks are shown One operation

minutes each week The tissues' power of recovery from the chronic effects of irradiation seems to be slight or nil, so that the status of a given individual's skin seems to be determined by the cumulative amount that he has had throughout his life

The triad of atrophy, telangiectasis and keratosis of the skin should lead to the diagnosis About the only condition that is to be differentiated is "sailor's" or farmer's" skin which is similar but is due to the cumulative effect of decades of overexposure to sunlight in persons who do not form sufficient melanin to protect themselves (in other words they do not "tan") This can be differentiated by the history and by the fact that "sailor's skin symmetrically affects both forearms both hands and the entire face and neck in most patients Telangiectasis is often predominant in x-ray burns whereas atrophy and keratosis predominate in "sailor's skin ' Coal spots rarely occur except in x ray burns Carcinoma may develop in either

The progress of a severe chronic x ray burn through the various stages of atrophy telangiectasis, "coal spots" keratosis and carcinoma is irreversible and inevitable if the patient lives long enough. It is not affected by any drugs or other means known at present except surgical excision and repair The stages may overlap, and the speed of the progress is greatly variable, so that it is often a major factor in deciding when and if to undertake excision Fast progress in any patient, and even slow progress in a young individual, are indications for treatment A paradox of treatment is that the excision and repair should be done when the area is in relatively good condition—not waiting until ulceration, pain and malignant change have occurred However, many patients wait until these stages appear, and the greatest surgical problem comes from this group

Faint telangiectasis and atrophy may not require treatment if it is very slowly progressive but excision and repair is some-

times indicated even in this group for cosmetic improvement

Bland ointments may soften "coal spots" and keratoses and may seem to stop them for a time, but the underlying pathologic changes are progressive and later become manifest On hands, keratoses develop with the "coal spot" stage and these may rapidly become malignant They can be removed best in mass and the areas grafted It is less desirable, but feasible in some patients, to do cautery excisions of the individual keratoses as they occur and let the areas heal by secondary intention These are the unusual lesions for which more radiation is sometimes recommended, but it should *not* be used as it is apt to accelerate the progress of the pathologic changes For the same reasons, carcinomas in x-ray burns should *not* be treated with more radiation

When it is decided that a radiated area needs excising, there are a few considerations that vary with size, depth, location, ulceration and malignant change in the area The basic therapy is wide, deep excision followed by immediate closure of the wound with free split-skin grafts The following variations are sometimes useful

1 Leaving the wound open to graft later This is because these areas are apt not to have a very good minute (capillary) blood supply (even though blood may pour all over the field from a few arterioles and venules), and with an inadequate minute blood supply, transplanted tissue does not survive

2 If the above is suspected, the wound may be "dressed" in a split graft with the patient knowing that the graft may not take and may have to be repeated

3 Definite plans for an immediate flap closure of the defect, either by adjacent flaps or distant flaps prepared ahead of time

4 Delayed closure of defects with pedicle flaps This is used when the area undoubtedly needs a flap, but when the depth of excision is uncertain, such as round the vertebrae or any place in which adjacent nerve supply must be protected

5 Flap coverage of exposed bone or tendons Free grafts do not do well over bone and will not grow directly on bare bone or bare tendon (if the area is more than a few millimeters wide), whereas pedicle flaps usually will survive and attach themselves successfully in such situations

There are two essentials (1) to get rid of the lesion and (2) to repair the area for useful function and appearance

The persistence of function of the skin grafts will be satisfactory if the involved tissue has been excised widely and deeply enough Edges should be watched, and if deep trouble develops, wider and deeper removal and repair may be necessary

The preparation of wounds for operation consists of local cleanliness, the use of mild local antiseptics (such as 1 5,000 aqueous Zephiran in daily wet dressings) and systemic penicillin For hands and feet, nonwettable agents (such as some of the silicate-gel preparations) may be used to prevent maceration of the surrounding skin under the wet dressings

These basic repair steps are used throughout the body, but some local areas may be considered separately.

Hands

Chronic x-ray hands occur most frequently in physicians and dentists and respond well to wide removal of skin and repair with thick split grafts The heaviest burn may be either on the dorsal or the palmar surface, but the opposite surface is nearly always involved to some extent Excessive pain may occur and require heavy sedation In lesions of very long duration, the individual gross blood supply to the fingers may be of such low quality that care has to be exercised in maintaining what is available, in not doing too radical operations, not sacrificin [illegible] arteries of [illegible] finger at one time [illegible]
tight When [illegible]
oped, very wid[illegible]
but the excision



Fig 288. Athlete's foot burn Extremely crippling x ray burns following treatment of athlete's foot. Resection of the lesion and immediate repair with thick split grafts. Two operations—one over the ankle and one over most of the heel

out sacrificing function so that amputation always has to be considered as possibly best and safest for some patients These lesions do not always remain local, and they always should be examined and watched for possible regional lymph node involvement One of the main difficulties, of course is getting physicians to submit to adequate operations

Face

Radiation burns of the face necessitate the added consideration of the appearance of the repair The paradox here is that radical operation should be done early, before the features have been damaged by the development of carcinoma. In some patients who usually have been treated for acne or eczema it is necessary to excise and replace the skin of the entire face—nose cheeks lids forehead eyebrows and chin If the excision can be done early enough so that free skin grafts can be used, the functional and cosmetic results are far better

It has been noticed that the little difference in closeness to the machine that the tip of the nose occupies usually produces

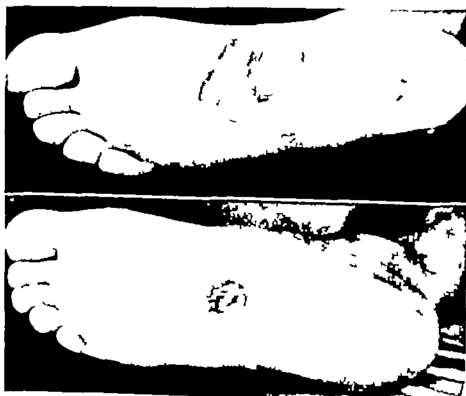


Fig 289 Fluoroscopic burn Extremely painful completely crippling lesion from one fluoroscopic examination following injury The involvement extends onto the dorsum Repaired in two operations by wide excision and split grafting

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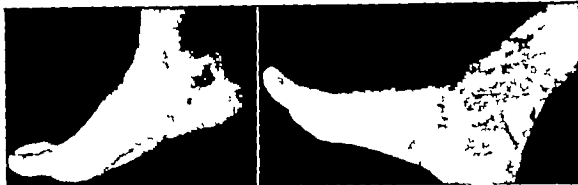


FIG. 288 Athlete's foot burn Extremely crippling x ray burns following treatment of athlete's foot Resection of the lesion and immediate repair with thick split grafts. Two operations—one over the ankle and one over most of the heel

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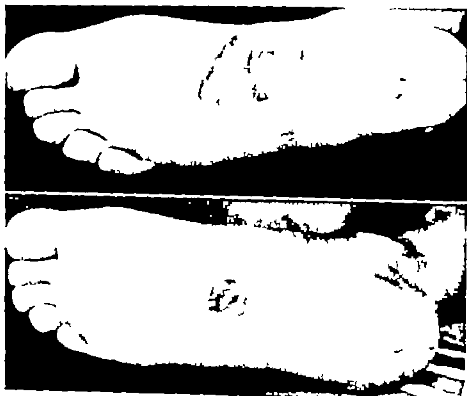


FIG 289 Fluoroscopic burn Extremely painful completely crippling lesion from one fluoroscopic examination following injury The involvement extends onto the dorsum Repaired in two operations by wide excision and split grafting

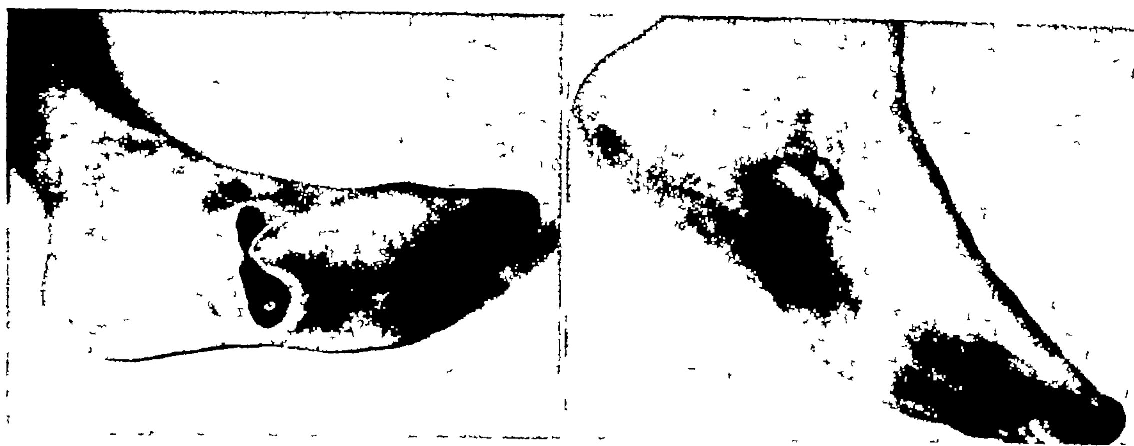


FIG 290 A burn of the sole of the foot extending so deep that a cross-leg flap had to be used, rather than a free graft Two operations

enough more radiation to cause greater damage here, and that there is also the added discomfort of a chronic mucositis of the nose, if not a burn clear up in it

Feet

Radiation lesions of the sole of the foot form a story of their own, with frequent histories of years of debilitation and great difficulty of repair Prophylaxis is as important here as in any region, because of the extreme and prolonged disability that may result

The rules of treatment are the same—excision and repair Free split-skin grafts can be used for even wide areas, if operation is undertaken before ulceration has occurred Small ulcerations, if not too deep, can often be repaired by local flaps or free grafts, but cross-leg flaps are almost always needed for repair of extensively ulcerated lesions The idea of cutting into the opposite sole for repair of a damaged one is mentioned only because it has been advocated and to suggest that it never be done

Fluoroscopic burns of the foot may cause some of the most distressing deep involvements seen Where the plantar fascia is involved, shreds may be extruded at intervals for months with total disability and considerable pain throughout that time The deep joint structures are especially apt to suffer in these foot lesions as well as the opposite surface of the foot The chronicity of the process far outweighs any value that may result from the examination

Rectogenital Area

Perianal and perivulvar burns (usually from treatment of pruritus) offer their special problems in repairing such contaminated areas and dressing such a difficult field Excision and immediate or delayed free grafting, or immediate shifting of local flaps inward and grafting their sites, is usually carried out Possible troubles from a circular scar near the pectinate line should be considered and avoided, if at all possible

Preoperative preparation may include enemas and laxatives to empty the bowel, and oral streptomycin or sulfasuxidine to reduce the bacterial flora Frequent sitz baths may help in preparing the local skin

At operation, the "stent" type of fixation may be used on grafts, with long-edge sutures tied over a pad of gauze to immobilize the graft and the dressing and the edges surrounded with zinc oxide or some other impervious ointment The use of a retention catheter and low-residue diet for from 7 to 10 days may help greatly in the prevention of soiling After that period, cleansing of the grafted area after each soiling is carried out, with the grafts usually becoming quite stable and requiring little further care after 2 or 3 weeks.

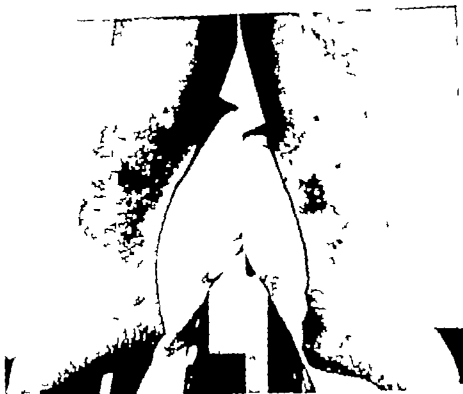




FIG 291 (*Top*) Commercial x ray treatment for removing hair resulting in almost total burns of the lower legs. (*Bottom*) Same patient after repair by wide resection and grafting. Surrounding involved area was done at a subsequent operation





FIG 292 Fluoroscopic burn (*Left*) Wide deep involvement following a chest examination This was repaired later in one operation (*Right*) Another patient shows result of a burn as at left, but with a direct flap added to cover a deep involvement The burn was the result of fluoroscopy

ENLARGING THE SCOPE OF RADIATION THERAPY BY SKIN GRAFTING

It is possible that the ability of the plastic surgeon to replace damaged skin may enlarge the useful scope of x-ray therapy in some instances

For instance, the child shown in Figure 293 had a rapidly growing hemangioma of the forearm, the hand and the arm This was ulcerating, sloughing, and growing so viciously as to behave as a malignancy

FIG 293 (*Left*) Rapidly growing, sloughing, ulcerating hemangioma of upper extremity in infant This was controlled by careful tangential radiation therapy, and the thin scarred skin was replaced later with split-skin grafts, as shown at the right







FIG 294 Abdominal wall x ray burn following treatment for a lesion of the gastro-intestinal tract. Complete excision immediate grafting. One operation with 8 days in the hospital.

locally A very skillful radiologist treated the extremity with care treating the surface tissues tangientally and shielding the bones and the epiphyses so that the arm was rotated around and treated in a number of tangential ports with a relatively nonpenetrating ray Only enough radiation was given to stop the growth and induce slow regression After the tumor was gone and everything was quiescent some years later the skin over the whole area was replaced with split skin grafts. This was necessary because of the multiple huge ulcerations that had healed with scar and because of the thin and atrophic character of the remaining skin that had been badly damaged by the hemangioma but also prevented any possible late radiation changes in the skin The knowledge that this was going to be done anyway was the deciding factor in getting the radiologist to treat her

A number of patients have been seen who had very extensive cervical and uterine cancers and had intensive radiation therapy with resultant controls of the cancers Many of these have required resurfacing of the radiated skin ports with split-skin grafts but the fact that they were well and ready to undergo this skin grafting from 5 to 15 years after the radiation speaks well of the treatment

One such patient was seen who required resurfacing of both buttocks 8 years after treatment for multiple peritoneal implants (proved by biopsy) from a testicular teratoma.

It is possible that the use of harder rays such as the cobalt bomb or the betatron may produce may obviate some of this but it still may be a better plan when treating serious malignancies to use "radical radiation" and later replace the skin rather than to try to save the skin by radiation too feeble to do the primary job

RELIEF OF PAIN BY OPERATION

Pain in these burns may be so severe and so refractory to sedation as to require immediate wide deep excision of the lesion with or without primary repair

When pain is so outstanding very dramatic relief is usually obtained by excision The patient upon awakening from the anesthetic and in spite of the discomforts of the operation will volunteer the information that his pain is gone

Severe pain may occur in lesions on the neck in areas adjacent to bone and in lesions along the vertebrae where root pain may be excessive One patient with severe abdominal pain who had a large burn of the

back, was nearly subjected to a laparotomy but was completely relieved of his abdominal pain by deep excision of the ulcer on his back (Fig 292) This is also especially true in patients with painful anal lesions

The pain from excessive radiation about the jaws is one of the most difficult types to alleviate

These lesions are unhappy ones from every possible aspect, and more of them occur than most people think Their prevention should be paramount in all instances of exposure Their occurrence should be recognized early, and complete excision and repair should be done before malignant changes take place (Fig 286) Such a regimen will greatly reduce the total amount of disability and suffering caused by them

It may be repeated that these lesions are progressive, and that surgical treatment should be undertaken before serious ulceration occurs and carcinoma develops

COBALT RADIATION LESIONS

Radioactive cobalt "bombs" produce a very hard short gamma ray, on the order of that produced by a 2-million volt x-ray machine, and are being used increasingly for therapeutic radiation, especially for difficult malignancies

Some spectacular cures have been obtained, and this in turn has led workers to try to treat more widespread and deep-seated malignancies with higher dosages, so that more extensive radiation sloughs and lesions have occurred, thus multiplying the problems of plastic surgical repair However, it is possible that the radiologist and the plastic surgeon together may succeed in salvaging some of these patients who were otherwise in an entirely hopeless situation

In general, the harder ray of the cobalt apparatus tends to a greater deep effect with a lesser effect on the skin Thus when damage and sloughs occur, they are apt to be deep and extensive, with great effect on the minute circulation of deep structures This vascular effect may be progressive for many months, and structures that appear viable 1 or 2 months after the radiation is terminated may undergo slow progressive necrosis some months later For instance, in chest wall lesions there may be progressive necrosis of the ribs, the intercostal muscles and other structures right down to the visceral pleura and the pericardium

The indications for resurfacing with free skin grafts are fewer in this type of injury, and the indications for repairs with permanent pedicle blood-carrying flaps are greater than in most ordinary radiation injuries

The requirements most often are for extensive surgical débridement, sometimes in stages, but ultimately far beyond the initial appearance of the lesion, and coverage with a prepared permanent pedicle blood-carrying flap, when such can be obtained

Other radioactive elements are also being used increasingly for therapeutic purposes Each has its own particular radiation spectrum, with regard to the proportion of beta and gamma radiation, and the hardness of the gamma rays, and different dosage and time technics are being tried Thus there will be some differences in the relative amounts of surface and deep damage according to these variations, but the general principles of repair are as outlined in this chapter

BETATRON RADIATION INJURIES

Apparently some of the betatron machines can be adjusted to emit varying proportions of beta and gamma radiation, but in therapeutic usage, at least in some institutions, they are adjusted to emit largely hard gamma radiation, on the order of a 2-million volt x-ray machine and somewhat similar to that from a cobalt "bomb" In these instances, repair problems may be similar to those from radioactive cobalt lesions

ATOMIC RADIATION BURNS

The occurrence of lesions from atomic radiation sources will increase as work in

turning mass into energy increases and if another war comes the incidence will be tremendous.

In areas already bombed, fire injuries have been greater in number than radiation injuries, but some of those surviving the blast and the fire and possibly many relief workers will suffer radiation burns

Many of the cases from Hiroshima and Nagasaki reported in the popular magazines and newspapers have been ordinary thermal burns not radiation burns, and are thought to be little different from any other thermal burn sustained elsewhere

The patients outlined in this chapter represent surgical repairs of pure atomic radiation injuries without any thermal component and may be of interest for that reason

Among workers in the development and production stage of atomic work, enough burns have been encountered to give indications of what to expect. The lesion produced by atomic radiation is not a new one entirely but the time element of the development is faster than in the accumulative x ray burn, due to the excessive exposure in a short space of time These burns usually arise from mistakes in security precautions and add the ever-present human element to the ultra in scientific work.

Whether the radiation is beta or gamma may not be definite in some exposures but as far as can be determined now the burns probably occur from both beta and gamma radiation Because of excessive dosage symptoms may begin very soon after exposure and blistering occur in from 4 to 6 days The blistering runs its course in about 30 days and there is either healing or sloughing with resultant open wounds, according to the degree of the exposure Exposures heavy enough to be fatal are not for discussion here Conservative treatment especially about the hands avoiding early amputation is indicated because hopeless-looking digits may be finally spared Relief of pain prevention of infection and general supportive measures are the main items of treatment. Blood changes are not significant in patients with exposures over small areas, but there may be emotional disturbances in workers that require patient guidance with recreating of hope for ultimate survival

Since these accidents are apt to be of excessive local exposure (12,000 r in a few seconds) more sloughing and ultimate atrophy may be encountered than in the usual x ray burn, so that ultimately more amputations may be required The pathologic processes may seem more contracted in time that is, the various elements of tissue changes may develop faster than in the usual radiation burn This also is probably dependent on the large sudden single exposure But these differences do not change the rule of being conservative in the acute stage

The pathology seems to be close to that already described for radiation burns (with the added sloughing and atrophy) and for this reason at least as far as the skin is concerned the same idea of treatment of excision and grafting is indicated but the burns are too recent to predict how soon carcinoma may be expected in ungrafted areas It could be expected in ungrafted areas earlier than in the usual chronic radiation burns from accumulative exposures.

Under the title of "Beta Ray Burns of Human Skin" Knowlton* and co-workers in 1949 reported on 4 cases of beta ray burns of the hands for the purpose of supplementing information in the literature and of emphasizing the early clinical courses, as well as the laboratory observations in such cases.

Theirs is thought to be the first report of human damage from atomic radiation and the present report is of the surgical care and repair of these injuries as carried out in consultation by one of us with these authors at Los Alamos and later in St Louis

To recall attention to these first patients with known atomic injury (without thermal

* Knowlton, N P., et al. J A.M A., 1949 141 239

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These lesions are unhappy ones from every possible aspect, and more of them occur than most people think Their prevention should be paramount in all instances of exposure Their occurrence should be recognized early, and complete excision and repair should be done before malignant changes take place (Fig 286) Such a regimen will greatly reduce the total amount of disability and suffering caused by them

It may be repeated that these lesions are progressive, and that surgical treatment should be undertaken before serious ulceration occurs and carcinoma develops

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turning mass into energy increases, and if another war comes the incidence will be tremendous

In areas already bombed, fire injuries have been greater in number than radiation injuries but some of those surviving the blast and the fire and possibly many relief workers will suffer radiation burns

Many of the cases from Hiroshima and Nagasaki reported in the popular magazines and newspapers have been ordinary thermal burns, not radiation burns and are thought to be little different from any other thermal burn sustained elsewhere

The patients outlined in this chapter represent surgical repairs of pure atomic radiation injuries, without any thermal component, and may be of interest for that reason

Among workers in the development and production stage of atomic work enough burns have been encountered to give indications of what to expect The lesion produced by atomic radiation is not a new one entirely, but the time element of the development is faster than in the accumulative x ray burn due to the excessive exposure in a short space of time These burns usually arise from mistakes in security precautions and add the ever-present human element to the ultra in scientific work.

Whether the radiation is beta or gamma may not be definite in some exposures, but as far as can be determined now the burns probably occur from both beta and gamma radiation Because of excessive dosage symptoms may begin very soon after exposure and blistering occur in from 4 to 6 days. The blistering runs its course in about 30 days and there is either healing or sloughing with resultant open wounds according to the degree of the exposure Exposures heavy enough to be fatal are not for discussion here Conservative treatment especially about the hands avoiding early amputation is indicated because hopeless-looking digits may be finally spared Relief of pain prevention of infection and general supportive measures are the main items of treatment. Blood changes are not significant in patients with exposures over small areas, but there may be emotional disturbances in workers that require patient guidance with recreating of hope for ultimate survival

Since these accidents are apt to be of excessive local exposure (12,000 r in a few seconds) more sloughing and ultimate atrophy may be encountered than in the usual x ray burn, so that ultimately more amputations may be required The pathologic processes may seem more contracted in time that is, the various elements of tissue changes may develop faster than in the usual radiation burn This also is probably dependent on the large sudden single exposure But these differences do not change the rule of being conservative in the acute stage

The pathology seems to be close to that already described for radiation burns (with the added sloughing and atrophy) and for this reason, at least as far as the skin is concerned, the same idea of treatment of excision and grafting is indicated but the burns are too recent to predict how soon carcinoma may be expected in ungrafted areas It could be expected in ungrafted areas earlier than in the usual chronic radiation burns from accumulative exposures.

Under the title of "Beta Ray Burns of Human Skin Knowlton* and co-workers in 1949 reported on 4 cases of beta ray burns of the hands for the purpose of supplementing information in the literature and of emphasizing the early clinical courses, as well as the laboratory observations in such cases.

Theirs is thought to be the first report of human damage from atomic radiation and the present report is of the surgical care and repair of these injuries as carried out in consultation by one of us with these authors at Los Alamos and later in St. Louis

To recall attention to these first patients with known atomic injury (without thermal

* Knowlton, N P., et al. J.A.M.A., 1949 141 239

injury) we may borrow from the report of Knowlton and co-workers·

All 4 men were injured while undertaking procedures . at the first atomic tests at Eniwetok Atoll (United States Atomic Energy Commission's proving grounds) This work involved the handling of radioactive materials which emitted large amounts of beta and gamma radiation A deviation in the prescribed procedure undertaken to expedite the operation resulted in the handling of these radioactive substances directly with rubber-gloved and sometimes with bare hands rather than with the remote handling devices that had been provided Measurement of the dosage of beta rays received by the patients was not obtained at the time of exposure, but film badge and pocket ionization chambers worn by the men over the thoracic region showed readings for gamma rays varying from 1 to about 15 roentgens In view of the fact that the hands were much closer to the active material, it must be presumed that the amount of gamma radiation received by the hands was somewhat larger, probably a factor of 10

The ratio of beta counts to gamma counts was about 6 to 1 The physical properties of beta rays are such that approximately 90 per cent of the incident rays are absorbed by the first 3 mm of tissue and 99 per cent are absorbed in 6 mm of tissue Estimates of dosage indicated that these 4 men received from 3,000 to 16 000 rep (roentgen equivalent physical) to the outer surface of the skin The beta ray dosages below the surface of the skin would then be 300 to 1,600 rep at 3 mm , and 30 to 160 rep at a depth of 6 mm It was believed that there was minimal, if any, danger of important whole body effect, and the patients were treated primarily for local beta ray burns of the hands This assumption was borne out in the course of the disease, in that at no time was there any significant evidence of other than local damage

These 4 cases were recounted in detail by the authors, and their "first" report is a milestone in clinical observation and laboratory study of patients afflicted with atomic radiation injury Anyone interested in the subject will want to study this report directly, and it will not be amplified here

A study of these first patients with atomic radiation injury (without thermal injury) is of great importance for purposes of investigation as well as for observation of their clinical course Theirs should not be confused with other accounts, in the popular press, of patients suffering from thermal burns of atomic bomb activity Such thermal burns are not much different from any other thermal burns and do not represent the problems or the pathology of the pure atomic radiation injury

To recount the early course of one of the patients, Knowlton and co-workers may be quoted

A white man aged 27 received about 15 r of gamma rays to his thoracic region and an estimated 8,000 to 16,000 rep of beta rays to his hands over a sixty minute period. During this exposure he experienced a sensation of itchiness in both hands Four hours later . all the digits of the left hand were swollen and erythematous There were no blanched areas on the left hand, and the right hand appeared perfectly normal

During the third and fourth days, there was a definite decrease in erythema of the left hand and there were no symptoms referable to the right

On the twelfth day vesicles began to develop in the erythematous areas Up to the twenty-eighth day there was spreading of the erythema, with bullae eventually forming in all such areas By the twenty-eighth day the bullae covered the volar surfaces of all the fingers and the distal portions of the palms of both hands

At about this time the erythema subsided The bullae dried up by the thirty-fifth day, and part of the dead epidermis sloughed spontaneously.

Débridement was done on the 39th, the 53rd, and the 67th days at Los Alamos, the areas finally demonstrating thin, glazy, tight epithelium.

All of these patients were seen in consultation by one of us at Los Alamos 3 months after the injuries. It was thought that the

conservative care given had been correct and adequate No amputation had been done and there were no blood or other findings to indicate general body or blood system injury One patient was thought to be well and possibly not to need any local treatment, with the reservation that late radiation changes might necessitate removal of the areas and grafting One patient was more noticeably upset mentally than the others, but he made rapid improvement when hope was given for his having useful hands. For 3 of the patients it was thought that eventual resection and grafting would be needed but no amputations were considered even though one terminal phalanx was questionable

Comment at this consultation was, *in brief*

These patients have received excellent conservative care and because of it the best possible outcome can be expected The records are excellent and invaluable. The question of biopsy study is still present, but such a study is thought best omitted in these hand lesions, as possibly causing too much debilitation and interference with the struggle for healing to be worth the value gained from microscopic study (Possibly in a flat area of the body where wounds might be easily excised and the edges collapsed together multiple biopsies could be considered and be found of importance.)

Continued conservative treatment is encouraged with frequent dressings—always under anesthesia when the patient desired—so that pain remembrance will be at a minimum Letting fingers out of dressings rapidly so that the least fixation of joints may occur is recommended Not doing forced manipulation of joints is stressed Suggest use of white cotton gloves and cold cream locally

Prognosis Possibility that chronic changes seen in the usual radiation exposures may occur and this should be guarded against, or at least be gone along with as follows (1) avoiding further radiation exposure (2) avoiding excess traumatic damage (3) avoiding excess chemical damage (4) possibly change of occupation details (5) routine observation of exposed area over a period of years (6) If the chronic changes become apparent, and persist to a point of telangiectasis or excessive atrophy, removal of involved areas and repair with free skin grafts (7) Joints prognosis unknown but probably good Do not think that they ever should be forced passively but let moderate activity be guide to recovery and usefulness.

The general prognosis is excellent for a normal life and normal usefulness of the hands

Recommendations and procedures basically were conservative treatment avoidance of amputation, subsequent removal of the involved skin and resurfacing the areas with free skin grafts These tenets were based on experience with radiation burns in physicians and patients hands and in one in particular treated many years earlier and reported in 1949 along with microscopic findings of various stages of radiation burns up to and including cancer formation The most notable patient was a doctor who had sustained approximately 75 000 r of x ray exposure from an unscreened fluoroscope and suffered acute burns almost identical with these atomic radiation burns He had complete blistering and such severe pain as to require 6 gr of morphine a day and to plead for amputation He was cared for by conservative treatment at the start and later by resection of the areas and resurfacing with thick split skin grafts. The result was a pair of useful hands and no loss of fingers except one tip which was necrosed by the exposure Further chronic changes around his palms developed and further grafting for these changes was necessary several years later, but the important point is that the hands were saved and the patient has been able to assume an important place in medicine in this country

With the experience in acute x ray burns as a background to go on these Eniwetok atomic radiation patients have been cared for in this conservative manner

Areas have been resected and resurfaced with free thick split grafts and good function has resulted in all the patients no



Fig 295 (*Left*) Atomic radiation lesion of the ankle in a laboratory worker (*Right*) Repair with split skin graft with permanent rehabilitation.

fingers have been removed, and all patients are at work in important atomic research and development It is now 8 years since the original trouble, and the areas of damage have been grafted as they showed progress toward chronic burns (Plate 9 and Fig 295) The grafting was carried out from the 7th month after the injury through the 2nd to the 4th year No serious changes have occurred since then, and no deep losses have been noted The patients have been urged to protect themselves, and they will be watched closely for any subsequent changes that may need removal and grafting Any possible deep vascular damage is to be recognized early and will be guarded against by urging avoidance of chemical, radiation, mechanical, or other trauma

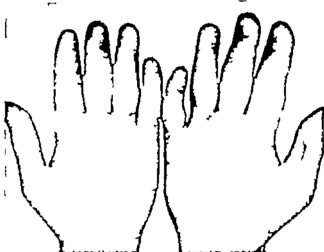
As proof of the need of avoiding mechanical trauma, 1 other patient was seen with a destructive cyclotron burn of the end of a finger which healed with conservative care and because of its small size did not need grafting (Fig 296) The patient was advised



Fig 296 Cyclotron burn of hand in research worker, with later spontaneous healing Still later there was an acute breakdown of a small area following trauma, but it healed again Eventually it may require grafting



PLATE 5









Atomic radiation burns of hands received inadvertently during bomb test Exposure of about 12,000 roentgens in a short period of minutes A small blistered area appeared in the first few days and progressed to the extent shown in (A, *top left*) 19 days later At 30 days the blisters had run their primary course. They had opened and were drying up as shown in (B *top right*) on the 36th day

(C *bottom left*) by the 40th day the residual of destroyed skin and open wounds was demarcated Some healing occurred subsequently but with thin glazy keratotic scar epithelium that could not withstand trauma of any kind and pain was severe.

(D, *bottom right*) Result of resection of the burned areas and resurfacing with thick-split skin grafts Operations were started 7 months after injury and carried out over a 2 year period Now the patient is working normally with care to avoid any type of severe trauma—chemical mechanical bacterial or radiation His rehabilitation is complete and has remained so for 7 years. (This result has been true of the other patients seen and operated upon at the same time No fingers or hands have been lost, and the conservative protective plan of care with replacement of the damaged skin seems to give hope for anyone so afflicted who has not sustained fatal body radiation)

to avoid trauma but inadvertently did injure his finger and suffered an acute secondary breakdown

A 6th patient was seen from an Atomic Energy Commission laboratory with an atomic radiation burn of the ankle in which natural healing had progressed about as far as it seemed it would go This injury was treated as any radiation burn with resection and grafting and permanent healing resulted Thomas L Shipman reported that in other small beta ray burns of the fingers early grafting performed between the 10th and the 14th days had given excellent results

Observations on the incidence of radiation burns in general source of, care of, and surgical repair of radiation burns, along with the pathology involved, have been reported by the Atomic Energy Commission Bowers and Brown and associates and by other authors as well and need not be repeated here A large volume of work of great importance has been carried out elsewhere and reported

We believe that these experiences in surgical repair with this first group of atomic radiation injuries (without thermal injury) in this country are valuable guides for the treatment of future patients who may suffer such injury and be fortunate enough not to have full body fatal exposure

33

Skin Grafting in Military Plastic Surgery

The military influence on plastic surgery has been great Modern plastic surgery received its start in World War I, and what was learned then was transferred to civilian use During the intervening 25 years, great strides were made, so that the tables were reversed in World War II, in that knowledge gained in civilian practice could be applied to military medicine for immediate use

Within the United States Army and Navy during the recent war were built the largest plastic surgery services in history and again young civilian surgeons gained knowledge that could be given back to civilians Before the war, however, the basis and the possibilities of work had been established and the younger surgeons could go ahead under the guidance of civilian surgeons in the services

A single item of interest in the change in plastic surgery, from one war to the next, is the use of free skin grafts In a 300-page report from World War I, no mention was made of skin grafts except as a part of one sentence Neither was any mention made of burns In the recent war, about one third of the work in plastic surgery was done with free skin grafts, and about one third for patients with burns

After World War I plastic surgeons in civilian practice developed methods and services for the repair of extensive burns, and, except for a short time during which excessive attention was focused on the irreversible sealing methods of treatment (tanning), steady progress was made in a basic philosophy of treatment of deep burns namely, to make open areas as clean as possible as soon as possible and to restore skin that has been lost Still further progress has been made in the concepts of treatment that aim at the start toward keeping burned areas clean However, the essential point remained that deep burns are apt to become infected, and certainly in military surgery all of them cannot be kept ideally clean Hundreds of patients have been cared for in the plastic centers with no skin on their heads, faces or hands, and with large open areas over the body and the extremities, with sloughs, contamination, infection, pain and when evacuation has been delayed, with the usual "blown" contamination that results from lack of change of dressing (Fig. 297).

These patients present all the problems of nutrition, chronic shock, blood chemistry and wound healing that may occur, and these complications are all dependent on open wounds Therefore, the basic surgical consideration is to get the wounds healed as soon as possible by means of free skin grafts Any spontaneous healing that may occur is welcome, but long delay in waiting for spontaneous healing adds pain, contractures and fixation of joints, as well as a chance for further depletion. As large open wounds heal, either spontaneously or by

grafting, the general condition improves proportionately In some instances grafting has been done in spite of the presence of local infection uncontrolled by chemotherapy, such a graft to close the wounds has been lifesaving Raw open areas as large as 200 square inches are frequently grafted at one successful operation It has been said that these extensive procedures, as well as others for the restoration of function in World War II would have been considered fantastic in World War I

While free grafts have been used most extensively in repairing burns, they have been applicable and valuable also in covering large open areas for other causes, such as gunshot and shell fragment wounds One of the most important areas to benefit from free grafting is the hands By early closure of burns and other defects of the hands,







FIG 297 (*Top left*) Total burn of the face, grafted early to obtain healing (*Top right*) Interim photo of contracted face with hundreds of buried whiskers that had to be removed (*Bottom right*) Contracted scars and imbedded whiskers dissected out later and full restoration made with free split skin grafts. Forehead cheeks lips, chin eyelids and nose all grafted (Brown J B and Cannon Bradford Repair of major facial injuries, Ann Surg 126 417)

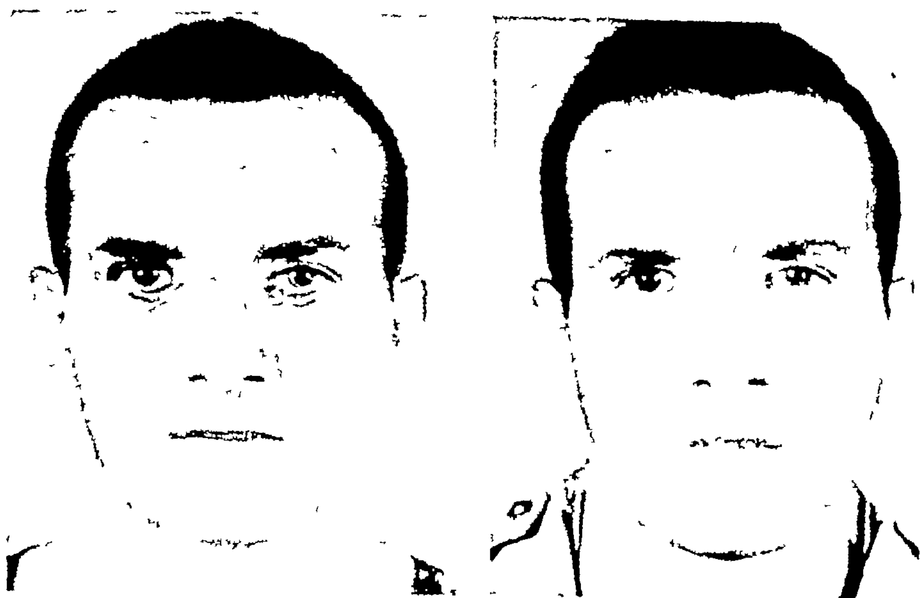


FIG. 298 Free full-thickness grafts from the clavicular region to recover the lids after dissection of the scar Two lids were done at one operation No secondary trimming was necessary (Brown J. B., and Cannon, Bradford, Repair of major facial injuries, Ann Surg 126·417)

many dramatic results have occurred in which function that otherwise would have been lost has been preserved This statement applies to the rest of the extremities and the body, and in several plastic surgical services only about one third of the work has been on the face

For making very extensive repairs, the split-skin graft, or some version of it, is used because in instances in which 250 square inches are transferred at one time it is essential that a method of grafting be used in which prompt healing of the donor site can be had If grafts are cut too deep, much added crippling may occur. In some instances it has been necessary to discharge patients because of trouble in donor sites that exceeded the original lesion

A special area about the face may be mentioned—the eyelids When eyelids are burned and contractures follow, the eyeball is left exposed, and impairment of vision may result In hundreds of instances satisfactory protection of the eyeball by the lid has been regained with a free skin graft to resurface the lids A special type of graft has been used for this work that is adaptable in function as well as in color and appearance. Such a graft is of full thickness and is taken from the clavicular region; the supply is limited, but it affords the best color match and, because of its character, presumably from its position in the platysmal area, gives excellent function (Figs 182, 298 and Plate 8)

Homografts have been used frequently to tide seriously ill patients over critical periods These grafts, of course, are not permanent, usually lasting from 3 to 12 weeks The wounds are literally "dressed" in the homografts These grafts can be taken at autopsy if complete releases for the procedure can be obtained from the patient and his relatives Such grafts have been taken as long as 4 hours after death and have been stored "refrigerated"

In the use of free skin grafts (as in other procedures in plastic surgery) a tendency has been noted to suppose, on one hand, that perfection can be obtained in difficult restoration of features and surface smoothness and, on the other hand to neglect simple procedures in grafting that could result in the healing of long-standing lesions or deformities. For example, one soldier was seen who had been off duty practically all of 9 years because of traumatic ulcers of both legs These were grafted in one operation, and the patient was sent to duty (Fig 299)

In lesions for which free grafts will not suffice, such as gunshot and shell-fragment

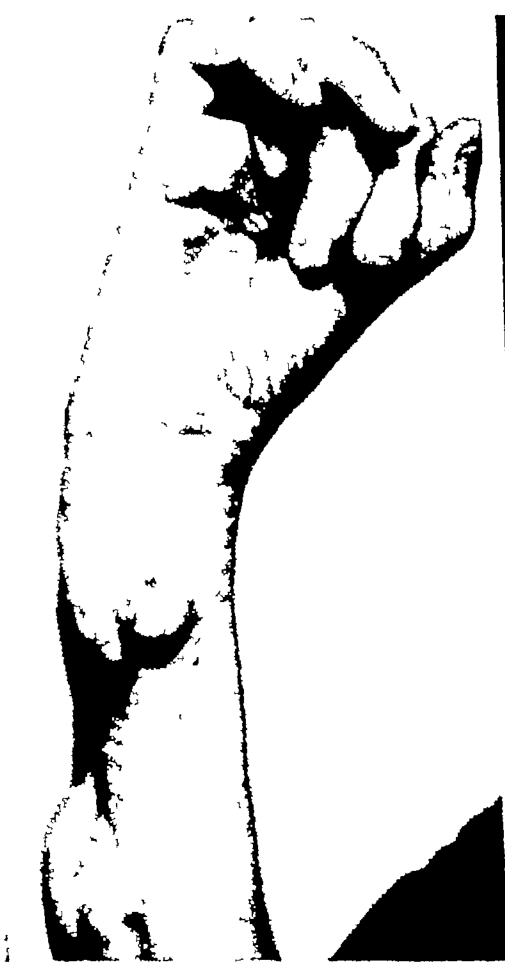


FIG 299 Chronic traumatic ulceration of both legs. The patient was disabled many years. Complete healing followed a single operation (Brown J B Closure of surface defects with free skin grafts and with pedicle flaps Surg Gynec. & Obst 84 862, 1947)

wounds and in cases in which features are lost restorations with pedicle flaps must be done Whereas in the past the majority of flap repairs have been done with tubed flaps it has been demonstrated in hundreds of patients that direct (or delayed) flat flaps can be used successfully The principle of a short broad pedicle is substituted for that of a long narrow tubed one and if the application can be made as a direct transfer (that is without delaying the flap) a procedure may be completed in days that otherwise might require months This has accounted for the saving for patients of thousands of months in a hospital

One of the main uses for the direct flap is in the repair of hand and arm defects The flaps can be put on at early dates following the injuries or later after the extremity has healed It is possible to cover practically a whole forearm with a direct flap from the abdomen in from 18 to 20 days and many seriously damaged extremities have been saved It might be said that these procedures are the opposite of amputation When applied early union of underlying fractures has been found to progress more rapidly and successfully and function is necessarily established at the earliest date (Figs 300 301 and 302)

In late deformities with surface scarring and with defects of nerves tendons bones and joints it is essential to obtain adequate surface "healing with a flap before satisfactory deep restorations can be done The deep healing can be no better than the surface healing and patients have been seen with wire foil screws plates bone grafts and bone fragments protruding through wounds that did not have adequate surface healing By removing dead and foreign material dissecting scar back to an adequate minute blood supply and making a repair with a flap of suitable thickness so that the deeper tissues can be approached through good viable tissue that will heal promptly and protect whatever repair has been carried out on nerve tendon bone or joint the orthopedic or neurologic surgeon has been afforded valuable assistance in his work This co-operation of the plastic surgeon with other services has been an excellent contribution and has resulted in saving many lives and restoring much function



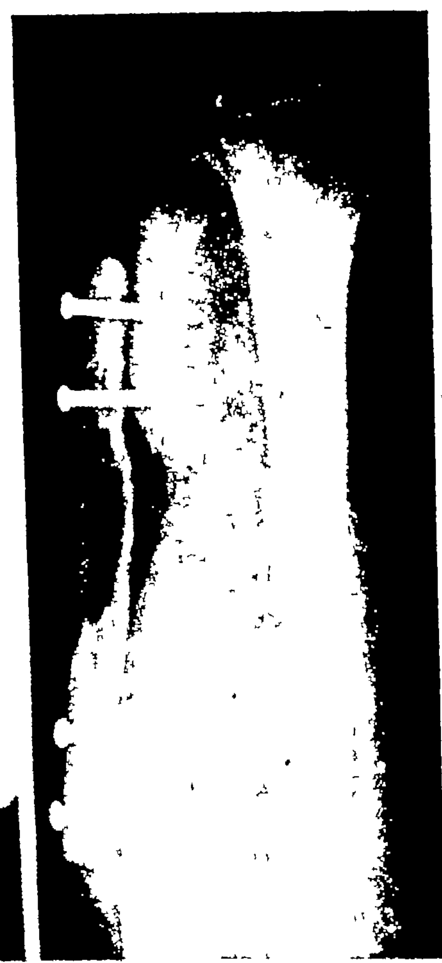


FIG. 300. Shell fragment wound of the arm, with loss of bone graft from the breaking down of the scar.

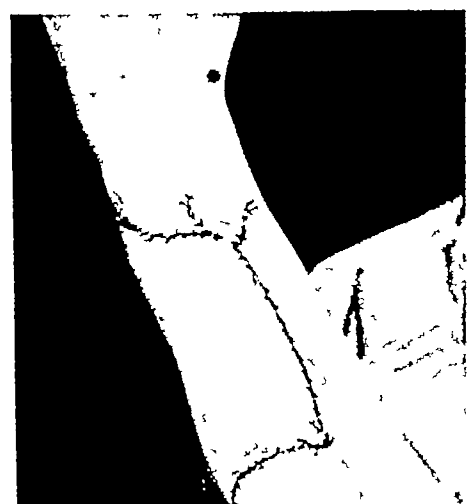








FIG. 300 (*Continued*). Extensive replacement of soft tissues with a direct flap and a successful secondary bone graft. A soft-tissue shadow of the flap may be seen also on the last roentgenogram.

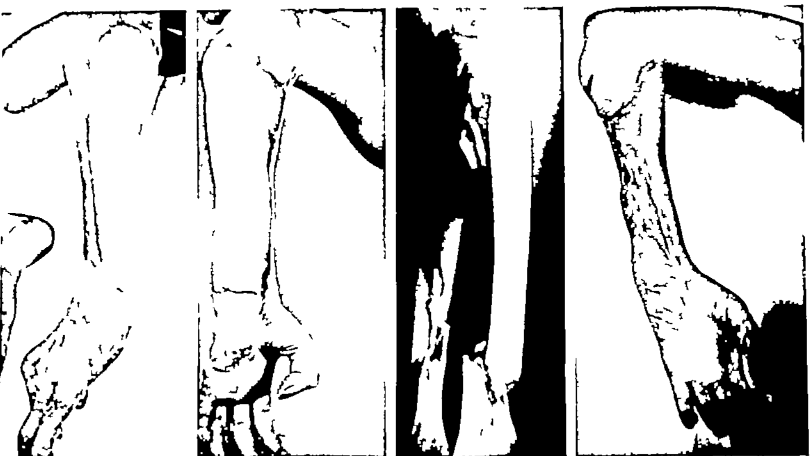


Fig 301A Extensive loss of soft tissue and destruction of bone showing widespread replacement of soft tissue in 18 days. (Brown, J B Direct flap repair of defects of the arm and hand Ann Surg 122 707)

In military plastic surgery, the three main lesions that have to be dealt with are: (1) gunshot wounds (including shell-fragment and powder wounds), (2) burns, (3) compound injuries resulting from traffic accidents and air crashes. These injuries are different in themselves, and they are different from those seen in civilian life—especially the shell-fragment wounds and the extensive burns. However, the patients in war are the same ones seen in civilian practice, and the anatomic and pathologic processes remain the same, so that much of the information that has been gained in civilian practice can be used as an excellent starting point for military surgery. For example, fine-mesh gauze for wounds, pressure dressings, cotton surgical waste, noncoagulating treatment of burns, early fixation of compound facial injuries and direct flap repairs of extremity defects have all been employed on various general plastic surgery services before the war. Many of these procedures were employed with as valuable results in military surgery, and as the differences between civilian and military surgery were learned, these proved methods were utilized to greater advantage.

Plastic surgery procedures are new to many surgeons in wartime and the difficulties are realized in many fields only after trial. Surgeons often want to know what is best to do, but each patient is usually an individual problem, and it is difficult to lay down standard rules. The following paragraphs are suggested as a conservative surgical viewpoint to aid in fitting difficult individual problems into the wholesale and mass-production care that may be necessary.

ESSENTIAL DIFFERENCES BETWEEN CIVIL AND WAR INJURIES

Dirt. Delayed evacuation up to 48 hours allows much dirt and contamination, so that even after patients have been returned to their home country, their wounds may still be showing the effects of dirt and of continued contamination and infection (Fig. 297).

Shell fragments, twisting and swirling around, and fragmenting tissue, winding up tendons and nerves, leave solid, immobile scar tissue in the softest kinetic areas (Plate 10). Where facial bones are involved there



Fig. 301B. Direct flap from the chest and the abdomen, preparatory to deep bone and tendon work. (Brown, J. B.: Direct flap repair of defects of the arm and hand, Ann. Surg. 122:707)

Fig 302 Gunshot injury of the hand with a direct dorsal flap after separation of the thumb from the fingers No deep work was required (*Bottom right*) The method of internal pin fixation to fix the thumb into position The nomenclature is indicated using 1 2 3 4 and 5 for the fingers, A, B, C for the joints and W X, Y, Z for the bones. (Brown J B Direct flap repair of defects of the arm and hand Ann. Surg 122 707)



Fig 303 Roentgenogram of the hand shown in Plate 10 (Brown J B et al Direct flap repair of defects of the arm and hand Ann Surg 122 707)



FIG 304 Complete loss of chin and surrounding soft tissue, the jaw is gone from ramus to ramus and the tongue is fixed out on the neck Restoration with large lined, flat flap from the chest Free graft to mobilize the tongue Flap defect was grafted at the time it was used A single bone graft of the entire jaw from the stump of the ramus on one side to the other was done with a single rib (Brown J B, and Cannon, B. Repair of major facial injuries, Ann Surg 126 267)

is a sort of explosion of them with multiple fragmentation and death of the chips Blasts of powder in areas of the body concealed by clothing make little difference, but in the face the ugly blackness requires removal

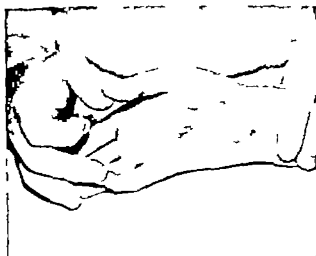
Shell fragments about the face and the head may knock out sections of skin and bone at any level of the skull, the eyes, the nose, the palate or the lower jaw. These lesions may differ in various theaters of war and according to the kind of warfare (Figs 304, 305, 306 and 102)

Gunshot or shell-fragment wounds of the

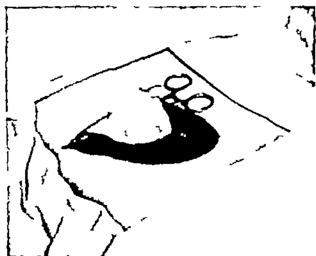


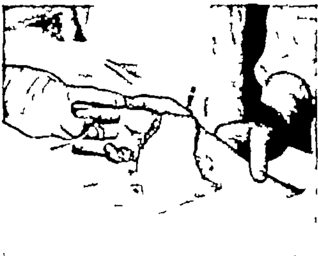
FIG. 305. Use of a distant flap for the nose rather than cut into the forehead A flat flap from the arm was used Cartilage for support ... color was ...h per- ...t in- ...ent ...a-

PLATE 6

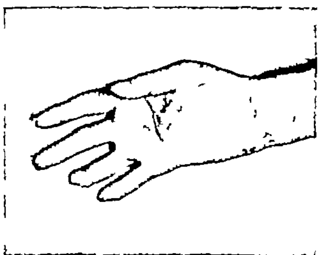












Multiple shell fragment wounds of the hand with resultant fibrosis Treatment consisted of widespread dissection with removal of the shell fragments encountered and repair with direct flap detached in 18 days. (Brown J B *et al* *Ann Surg* *122* 707)



FIG 304 Complete loss of chin and surrounding soft tissue, the jaw is gone from ramus to ramus, and the tongue is fixed out on the neck Restoration with large, lined, flat flap from the chest Free graft to mobilize the tongue Flap defect was grafted at the time it was used A single bone graft of the entire jaw from the stump of the ramus on one side to the other was done with a single rib (Brown, J. B , and Cannon, B. Repair of major facial injuries, Ann Surg 126 267)

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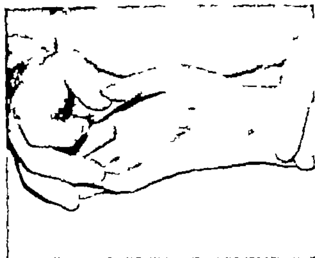
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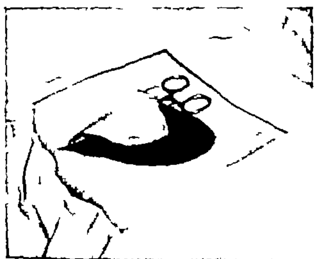


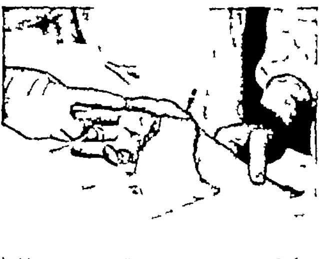
FIG 305 Use of a distant flap for the nose, rather than cut into the forehead A flat flap from the arm was used Cartilage for support and final color was obtained with permanent pigment injection The patient has only travel vision (Brown, J B., and Cannon, B . Repair of major facial injuries, Ann Surg 126 630)

PLATE 6

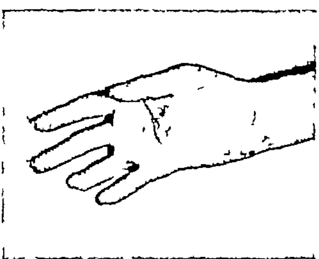












Multiple shell fragment wounds of the hand with resultant fibrosis Treatment consisted of widespread dissection with removal of the shell fragments encountered and repair with direct flap detached in 18 days (Brown J B *et al* *Ann Surg* *122* 707)



FIG 306 One of the worst types of composite and compound injury Restoration with local tissue free skin grafts and flat flap from the arm for the nose. Cancellous bone graft for the jaw Cartilage support for the nose. (Brown J B and Cannon B Repair of major facial injuries, Ann Surg 126 629)

face are only a part of the problems of repair that are required The extremities take up 56 per cent of the body surface, and extremity wounds are not as likely to be fatal as those of the head the chest and the abdomen For these reasons a large percentage of war wounds are of the extremities and *one of the functions of the plastic surgeon in the combat zone is closing these wounds with skin grafts* When the wounds have contracted and have deformed tissue and disrupted function the resection of scars and replacement with skin grafts or flaps are important parts of the work

FREEZING INJURIES

Freezing injuries occur far more often in military surgery than in civil life They result mainly from high altitude flying with exposure from accidents of shell fire They also occur from excessive exposure on the ground The immediate treatment is the subject of investigation and was first studied by Dr Loyal Davis in the European theater

As far as plastic surgery is concerned the immediate treatment should be conservative of tissue and secondary repairs should be made as necessary One of the worst

FIG 310 Defect plus scar about malleolus that probably would not carry either a graft or a distant flap Local delayed, rotated flap used to carry its own blood supply Donor site carefully covered with thick split graft The whole area is firmly healed and with adequate care will give satisfactory function. First operation flap raised and undermined Second operation flap cut across distal end Third operation flap shifted after excision of scar, and donor site grafted (Brown, J B, and Cannon, Bradford The repair of surface defects of the foot. Ann Surg 120 417-430)



FIG 311 Small insignificant-looking graft put on after resection of painful scar Soldier had been off duty and was ready to give up because of discomfort Following relief of pain and healing with the thick split graft he requested return to duty. One operation (Brown, J. B and Cannon Bradford The repair of surface defects of the foot. Ann Surg 120 418)

pedic and plastic surgery affords the best chance for the patient

The repair of gunshot and shell fragment wounds usually requires flaps rather than free skin grafts such as those that are generally satisfactory for burns The reason for this is the deep scarring that usually occurs and the frequent necessity for doing deep definitive work on bone, tendon or nerve later (Figs 300, 301, 302 and Plate 6)

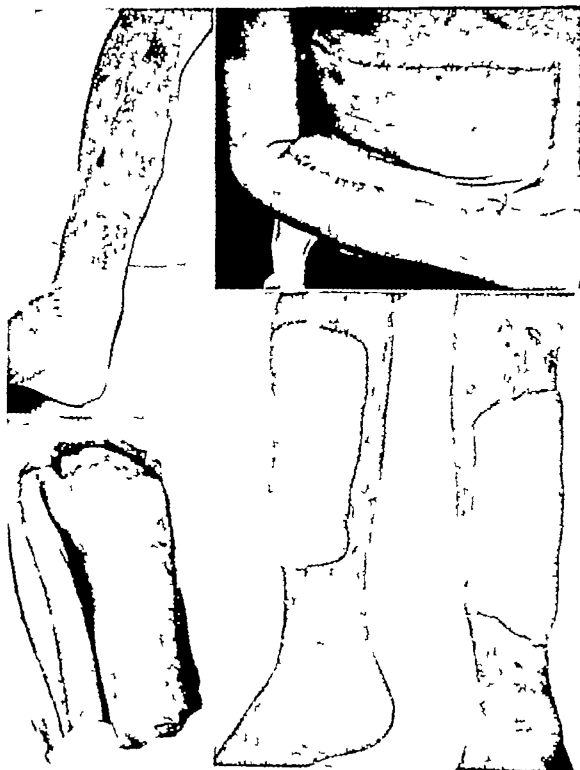


Fig. 312 Resurfacing of entire front of lower leg with single open jump-flap from abdominal wall The 7 operations required 12 weeks. (Cannon, B Lischer, C and Brown, J B Surgery 22 335)

fragment to fragment for support of a gap were first used in the immediate repair of a wide bone loss and may be used at the time of original treatment or in jaw resections for tumor However, the final repair, especially in young patients, is thought to be best with a fresh autogenous bone graft that he can call his own and depend on

Source of grafts is usually fresh autogenous ones from the ilium or the rib, both of these supply cancellous bone that would seem to graft and persist better than a solid, dense, cortical graft from the tibia Completely cortical (or chip) grafts to try to obtain a better blood supply for healing are thought by some to be advisable However, they do not lend themselves to immediate solid fixation without tooth wiring or splint support, and the more solid type seems to be superior if the bed is adequate Cancellous-to-cancellous bone might give the quickest union but it still would not allow firm, independent fixation unless some firm cortex were left for wiring However, this is a technical point that is decided in individual cases by different surgeons

Bone and cartilage grafts are sometimes used when the whole side of the jaw is out, including the condyle In this instance a section of the 6th or 7th rib is removed along with the attached cartilage The angle is a fairly normal one for the jaw contour, and the cartilage end floats free in the glenoid region There is no special joint fulcrum, but the extent of fixation may be adequate for improved function and position

Size of the graft in length does not seem to make much difference so long as a suitable one can be obtained and fixation maintained in a satisfactory bed Single rib grafts from one ramus clear around to the opposite ramus have been successful. Bridging the whole side of the body is frequently done, with good stability and strength resulting Occasionally, very large grafts may be put in first and fixed to the fragments secondarily.

Immobilization of graft is from 8 to 12 weeks, according to needs Function is often close to normal, depending, of course, on the available teeth, the lack of severe "turn in" of the fragments and the success of the dental prosthetic appliance Later these may not find a good bearing surface in extensive in[illegible] repair, but the ingenuity of the dental prosthodontist usually produces a worthwhile appliance

Final building out of the jaw to restore normal profile may be done with onlay bone graft, cartilage or foreign subcutaneous prosthesis as desired

Regeneration of the jaw has been noted and reported by us previously It has been found that in infections there may be complete loss followed by complete regeneration of the body of the jaw. However, this has not been seen to occur in traumatic loss or surgical removal and therefore is not relied on In infections the reason is possibly because destruction and regeneration presumably are going on at the same time, whereas in trauma the whole area is lost at one time permanently, whether some periosteum has been left or not

The preliminary soft-tissue preparation and replacement is done before the bone graft is put in but is described here secondly because bone grafting has been taken as the main subject

Flaps for repair of the soft tissues are designed according to the extent of loss and of scarring Local flaps, as in all plastic surgery, can be considered but are not used for very large losses as they might result in further scarring and collapse of the fragments of the remaining jaw Rather than this, it is better to fill the defect with soft tissue from a distance and let the bone fragments separate to their original normal positions

A permanent pedicle blood-carrying flap can be brought up from lower in the neck and the pedicles left intact so there is a new blood supply to the area brought in permanently by the flap. This flap is used if there is not a very wide loss of tissue The usual flap is somewhat of a drain on the blood supply of the area when the pedicles have to be divided

Distant delayed pedicle flaps are brought up from the chest when there is a large loss They have to be lined if there is not enough mucosa available, and the lining is turned in as a secondary flap or supplied as a thick-split graft under the pedicle when it is first raised. Flat flaps are usually relied on but the pedicles can be tubed if this will make shifting easier

Tongue [illegible] it on the neck should



FIG 313 Severe war gunshot wound of the lower jaw area, with final repair shown on the right. See text and Figure 314 for details of repair The patient was cared for at Valley Forge General Hospital

be freed and mobilized before the flap or bone graft is done or the tongue may never be free Usually the scar can be resected and the tongue loosened to go back into place The defect can be covered with a free graft, preferably a full thickness one from above the clavicle to give the best function and softness, or with small local flaps. If there is extensive loss of tongue there is all the more reason to try to get it as free as possible as speech with a fixed stump may be very difficult

Salivary flow out onto the chest has to be stopped before the bone grafting and if there is no wide loss the first consideration is to mobilize lateral flaps and close the floor so that the saliva will go back down the throat instead of out on the chest. This is important as a morale builder because the patient who is freed from this constant annoyance believes that he has made great progress toward recovery However merely to cause this flow to be reversed is no reason for further distortion and collapse of the floor rather than adding a sufficiently large flap with necessary lining.

Excision of scars and closure in stages has almost no place in this type of injury It collapses the fragments fixes the tongue and may leave the saliva pouring out Much difficulty has been encountered (mouths being pulled open and saliva pouring out, eyelids pulled down from the globe and emotional expression interfered with) in wounds of the face when the principle of excision and closure has been applied to wounds of too great extent

Anesthesia for this work is most important and needs careful consideration and co-operation. When safe general anesthesia is available, there is little use for local, but if necessary the whole work can be done under deep block of the 5th and the cervical nerves and infiltration

Tracheotomy may be already present and can be left open until the major work is done However it may interfere with the work and, if so the opening may be allowed to heal as soon as it is safe to do so

Pressure fixation dressings are necessary throughout all these procedures as much so as almost any step in the procedure both for the preliminary flap and for the bone graft

Joint and coronoid fixation of the remaining jaw fragments is rare but if it exists steps to relieve the fixation should be carried out first, for there is not much reason to graft into an ankylosed jaw

A fascial sling put through an inert flap and anchored in each temporal region may be necessary to hold up the thick lip So far no one has ever built a sphincter, which the





FIG 314 Same patient as Figure 313 A folded flap from the chest, to supply lining and coverage, was applied to the chin and the lower lip area, to make a watertight mouth and to provide a satisfactory bed for later bone graft (shown in roentgenogram on the right) of rib to mandible

mouth is, but substitution can be made for it The larger flaps are attached high so that the middle third muscles can help, and there has to be a balance between some limitation of opening and the mouth's remaining watertight, and the mouth's being watertight but still able to be opened

Tattooing or pigment injection may be useful to simulate a vermilion, and *speech training* may be required if there is difficulty in the patient's use of what is left for him to work with

These patients fortunately suffer but little pain at the moment of the accident, even though the 5th nerve roots are torn out However, there is agony and despair to follow, and the challenge of surgical restoration and of their own rehabilitation is one of the most demanding in surgery of this type

Final good surgical restoration is usually possible, and inspiring rehabilitation mainly by the patient's own effort, is seen in most of these unfortunate patients

The case illustrated is described in full, not as a case report but as a typical example of war *injury and repair* (Figs 313 and 314) In this boy there had been early saving of life in the first echelon by forward surgical officers and nurses and men, and with immediate tracheotomy Late surgical restoration included a delayed flat flap from across the chest, with a side flap turned in from above to line the flap and form the lining of the inside of the mouth Because of wide loss and not wishing to collapse the bone fragment further, the salivary flow onto the chest was not reversed until the flap itself was put in place to make the mouth watertight

After the flap was solidly in place, soft and without induration, a large (12 cm) bone graft from the rib was put directly in place, utilizing its own solidity and solid wire fixation for splinting so that the graft became its own *splint In this instance there were no teeth for* fixation, but no internal wires or external splint was necessary, only the graft itself wired in solidly.

GUNSHOT WOUNDS AND DEFECTS OF HANDS AND ARMS

Gunshot and shell-fragment wounds that can be repaired nearly always *need* flaps In these areas there is an excellent source of



FIG 315 Widespread loss from shell fragment Restoration in one single operation with free skin grafts (Brown, J. B · Closure of surface defects with free grafts and with pedicle flaps, Surg, Gynec & Obst 84.862) (cf Plate 3)

in this book "the deep healing can be no better than the surface healing"

To start putting in the outside of a repair first, that is the flap, and then to put in the bone might seem to be working backward and not like any other mechanical construction in which the support or armature would be constructed first and then the walls built around it But these fundamental ideas are important to recognize in the over-all approach to the problem

This method was used and reported before the war, but military plastic surgery supplied thousands of instances for carrying out the method successfully. It was found, too that very early application of the flaps hastened deep healing and bone union. The first direct flap that had been used many years before the war was on a gunshot wound of the hand, only 8 days after the injury and in an instance where amputation had been recommended

One criterion for saving arms is that if the nerves are intact every effort should be made even if amputation has to be done later Besides this, however, when nerves are lost, if the circulation will survive then flaps should be done to give a chance for nerve dissection and repair, or tendon substitutions

In this simple, direct method of skin and soft tissue replacement is found one of the most useful plastic surgical procedures, and in the combination of plastic and orthopedic and neurologic surgical work, many seriously damaged hands and arms have been saved

DEFECTS OF THE LEGS AND THE FEET

These defects present much the same problem as the arms and the hands, but the solution is much more difficult, chiefly because no good supply of flap tissue is available Other difficulties are interruptions of sensory nerve supply that give permanently anesthetic feet and attendant recurrent ulcerations regardless of the success of the repair, and the highly specialized tissue of the sole, which cannot be replaced entirely but only substituted for Transplanted tissue does not metaplase and does not develop into a normal sole once transplanted If hair-bearing tissue is put on the sole of the foot, it will remain as such, and the subcutaneous tissue from a "cross-leg" or thigh flap never takes on the firm, trauma-resisting characteristic of the normal sole

Local flaps with preservation of important sensory nerve supply are usually preferable to any other type of flap One should be hesitant about cutting into a good leg to make a repair of another without excellent assurance that crippling will not result Complicated caterpillar and jump flaps from the abdomen may become surgical monstrosities, and again the simplest, most direct flap is often the best the thigh is usually prefer-

able to the lower leg for a cross leg flap unless it is a very small one A long tubed flap up the anteromedial aspect of the thigh is useful for the heel and the lower leg if position is difficult to maintain with a flat (nontubed) flap (Figs 308 and 315)

Avoiding injury to the donor leg and avoiding the loss of important sensation to the leg and the foot are extremely important considerations. One cannot help being deeply impressed with the extreme difficulty of replacing lost tissue on the leg and the foot

Perhaps the best, quickest and safest repair of a defect of the lower leg or the foot is an open flat flap from the abdomen brought down on the arm One starts with the principle of a short broad pedicle for the flap and then brings the flap over on the arm in one stage Then it can be detached from the abdomen in one or as many stages as desired

In making the shift to the lower extremity the same principle of the short broad pedicle is followed for the transfer to the recipient area and the flap is put directly into place when it is detached from the abdomen (Fig 311)

SENSORY NERVE SUPPLY OF DAMAGED AREAS AND OF FLAPS AND GRAFTS

Sensory nerve supply to the foot is extremely important Most lesions show recovery either spontaneously or following operation. Sensation may become almost normal in flaps and grafts also—so that both epicritic and protopathic sensation is satisfactory However if the nerve supply is blown clear out or is totally blocked in its return then large areas of scar of normal skin and of flap or graft may remain anesthetic and there is little to be done except be eternally vigilant and protect the area from trauma infection heat and cold

DECUBITUS ULCERS

These ulcers can occur in any debilitated patient and are frequently seen in burned patients over exposed bony areas such as heels elbows and pelvic prominences In these patients the sensory nerve supply is seldom lost and the repair of the lesions is relatively simple if not much bone is exposed or sequestrated Many of the lesions heal of themselves as the patients wounds are closed or healed Others may require local rotated flaps or free grafts for repair as shown in Figure 138

In paraplegics or patients with a local nerve out the problem is extensive and distressing The main elements of care start with the patient s general care and with protection of the areas from further pressure and irritation Cleanliness of course is of primary importance

Some of the wounds can be excised and closed when clean enough on others free grafts may be used Rotating in adjacent flaps and closing or grafting their own defects is one of the most widely used procedures. Usually distant flaps are not relied on because of the technical difficulty in these crippled patients.

One of the most important steps is to get rid of the dead and uneven bone even if fairly large resections of it are necessary There is no use trying to use either free grafts or pedicle flaps over dead bone

BURNS

The following paragraphs are included to round out the military aspect of the general procedures

The primary treatment of burns may greatly influence the final outcome and it is as a result of the observations of plastic surgeons that coagulating methods of treatment have been given up No one plan of treatment is applicable to all burns in all military situations but for deep burns one usually can follow the simple rule— get the areas as clean as possible as soon as possible and restore what skin has been lost with skin grafts

Early bursting of burns is the ideal pro-

cedure, and most of them can be cleaned up, sloughs separated and the patient generally ready for operation in from 20 to 30 days This requires open surgical drainage, débridement and general supportive measures for the patient Chemotherapy, soap and water cleansing, fine-mesh gauze and pressure dressings are requisites that have become almost standard procedures (Fig. 112)

Immediate grafting of burns by wide debridement of the area and applying free grafts has been suggested at intervals for a long time, Murat Willis being the most-quoted author While this might be useful in certain types of burns in certain areas it could not be applied universally, as too much good skin would be wasted at times and too little burned area removed at others Also, it naturally would not be applied to widespread burns of the face and the hands

Thick split-skin grafts of from one half to four fifths the full thickness of the skin are used on nearly all raw surfaces and open wounds and are also used on many late healed deformities that have to be opened and the parts dissected back or returned to their normal position

Full-thickness grafts are still used at times on exposed surfaces, as the face the neck and the hands, when it is important to gain the best and quickest good cosmetic result

Z-flaps are used sparingly in plastic repair of burns although they are reported very frequently The reason they are used sparingly is that their utility is low In the first place, they are scars themselves and do not do well as direct flaps, in the second place, bad contractures have lost more skin than they can restore They are useful if there is only a webbing without deformity, but this occurs only infrequently and then only after a long period from the time of the burn For example, if an arm can be raised clear above the head, but there is a web, then the web will suffice for the repair If it cannot be raised clear above the head, then there is so much scar that skin will have to be added to permit complete function

The process of using the flaps is not to dwell so much on the Z or reversed Z but to split the web so that two surfaces exist and then fashion flaps so that they cross or fit into each other They are usually about 60° angles with bases opposite each other, but they may be W- or U- or T-shaped In all repairs, all available or usable skin should be used, of course, but if the flaps do not permit complete function, then the edges still can be placed in their normal positions and skin grafts added

Pedicle flaps, of course, have to be used if features are missing or if thick padded repairs are necessary, such as on the sole of the foot, but whenever they can be omitted in favor of free grafts, much time and expense can be saved

OTHER ASPECTS OF PLASTIC SURGERY IN WAR

Much plastic surgery has been predicated on the repair of defects resulting from cancer, but the older patients with lax tissue available for repair do not present quite the same problem as the 18- to 25-year-old youth who has had his face blown away in a second, with total destruction of features These young patients deserve having the minimum of additional scarring and having repairs that will give the least possible residual deformity The annals of surgery display no greater courage and will to live on the part of patients, nor more earnest work and hope on the part of the surgeon, than were found in World War II in the doctor-patient relationships in such cases as these

Mass-production methods do have to be used when hospitals are flooded with battle casualties or in massive civilian catastrophes, but this involves mainly such life-saving measures as early grafting of burns No matter how great the number of cases a nation has to deal with, from a fallen soldier on the field to the restored patient

walking out of the plastic surgery center, there is no substitute for individual doctor patient relations This cannot come from central direction but has to come from the surgeon himself, and without it little success can be expected The work often appears to be endless both for the patient and the surgeon, and the surgeon realizes only too well that the best possible result will still be short of his wishes or of what the patient deserves These men are individuals and have to face all the problems involved in getting along with other people that anyone does, they should not be grouped together as a class or given up as hopeless because of the difficulty of the repairs they require

In the military experience included the deepest appreciation is felt for the work of Dr Bradford Cannon and Dr Andrew Moore and other surgeons associated in the work. To Miss Virginia McCall is extended the greatest respect for her understanding of the human problems of injured soldiers, and for her technical skill and artistry in recording the lesions suffered by these injured men. Thanks are expressed also to Mr Kent Hoser for his photographic recording.

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Faults of Skin Grafts

FAILURE OF GRAFTS TO GROW

Failure of grafts to grow may be due to the slipping of the dressing, to the movement of the graft bed, or possibly, in the case of full-thickness grafts, but not in any other kind, to too much pressure Collection of blood under any sizable area will prevent a "take" There is also the possibility of insufficient blood supply for the graft; sometimes this is seen when not enough scar tissue has been removed and, in some instances, when there is a dry area in the graft base in an otherwise oozing field.

The causes noted above will not result in complete failure, except in a few instances, and with careful attention to after-care, much of the graft may be saved and the secondary repair simplified

Infection is the most frequent cause of failure and may cause total loss of the graft *Bacillus pyocyaneus* is the most frequent offender, and next in frequency the skin staphylococci and respiratory organisms (especially streptococci), which may produce serious results in any operation whether it is a laparotomy or a skin graft Very active care, depending mainly on well-carried out irrigations and surgical drainage, may save large amounts of the graft

Note This chapter is included as a reminder that grafting from a cosmetic standpoint may leave much to be desired It could be much expanded, especially if illustrations of failures were shown These are fairly well known however, and as in all reparative work, one should know the limitations as well as the possibilities A failure one time does not preclude an improvement by further procedure usually

Local and general chemotherapy has been of assistance both in the prevention and the after-care When the wounds are clean enough and the patient's condition satisfactory, a secondary repair can be done, usually using a thick split graft

Two types of failures of grafts need especial mention One is that seen occasionally after the removal of a very thick scar or keloid and thought to be due to the presence or organisms deep in the scar tissue itself The second is the case of radiation burns in which these organisms also may be present Moreover, these fields are notoriously bloodless and sclerotic

CONTRACTURE AND WRINKLING IN GRAFTS

Contracture following grafting occurs mostly in the tissues underlying the graft and not in the graft itself This may be evidenced by an actual wrinkling of the graft as the field contracts under it.

This occurs differently in various situations, of course, and may begin after a few months in some patients, while others will require secondary operations Careful and complete release of all scar contractions during the opening, and the most rapid healing possible afterward perhaps will do most to prevent this In general, also, the thicker the surface repair, the less will be the subsequent contractures Contractures are less apt to occur when grafts are placed over a bony framework, such as the forehead or the skull, or over regions acted

upon by strong and active muscles such as the axilla or the knee.

Deep infection under a graft from organisms possibly held in the original deep scar may cause excessive contraction under a graft that survives in this situation Similarly infected and persistent sebaceous collections under a graft may keep up the wound stimulus and promote contracture

Wrinkling of free skin grafts occurs most frequently in the Ollier Thiersch the thick split and the full thickness grafts in this order It is usually due to contracture of the underlying bed This wrinkling is most apt to appear about the 3rd or 4th week in split grafts but may smooth out so much in time that after 6 months it may be impossible to distinguish one of them from a full thickness graft If the graft has been put on a relatively flaccid area however this contraction and wrinkling may progress so that the actual width of the graft may be reduced several times This is apparently an effort of the original defect to close completely in spite of the presence of the graft Deep massage and careful surface radiation soon after grafting may possibly retard this but little optimism can be felt in this regard

KELOID FORMATION

Keloid formation is only one more activity presumably of the same origin to which the graft may be subjected There may be keloid formation around the edge and in every suture hole and there may be actual keloid development under the graft so that its surface is extremely irregular This is especially apt to occur in fat little girls and here it is thought that the actual tension of the skin which is distended with excess subcutaneous fat acts as a wound stimulus and the excess fibrous tissue develops wherever there is any surface weakness

This tendency is especially bad if small grafts are used such as along a finger or about the face and the neck. The actual contraction of the keloid along the edge of an otherwise normal graft may reproduce the original deformity, at least in part There is not much that can be done about this situation although many ideas have been advanced Probably the best thing would be for the patient to lose a few pounds of weight and certainly she should not gain Surface radiation is usually used if the areas are bad, but we have not seen any very brilliant results from it, and the thin epithelium over these keloids may be easily damaged

It seems to be fairly definite that buried epithelial débris, such as ingrown whiskers and other skin appendages, may cause keloid formation It is mentioned here again because of its importance, that in resurfacing men's faces it is necessary to resect the scar surface down below the whiskers This usually requires a fairly deep dissection because the hair follicles extend through the skin proper down into the strata just between the dermis and the obvious subcutaneous tissue

SEBACEOUS COLLECTIONS UNDER GRAFTS

These may occur under thick split grafts especially and do so with marked variations in different patients A split graft may look perfect soon after it is applied and then in 3 or 4 weeks wrinkling may begin and little collections of sebum may appear under the surface. These should all be evacuated by pressure with or without a small sharp incision over them

Occasionally large collections may develop (Fig 316) These may be due to the cut ends of glands secreting backward, or to the covering over of small remnants of scar epithelium or deep glandular epithelium Their importance is that final healing may be delayed and if they become infected excoriation or even loss of part of the graft may occur There is usually a layer of deep epithelium under these collections so that if they are opened and ex



FIG. 316 Biopsy of large sebaceous collection under graft These possibly originate from sebaceous glands without suitable drainage, or may be inclusion cysts resulting from covering remnants of scar epithelium with the graft They may produce local necrosis by pressure or infection and should be drained as soon as they are observed.

pressed and any overhanging edges trimmed away before infection causes damage, serious loss is avoided. The occurrence of sebaceous collections is markedly variable, some patients not showing it at all and others showing it badly, regardless of how thick the graft is cut However, full-thickness grafts never show it

PIGMENTATION OF GRAFTS

It is an unhappy situation in the field of reconstructive surgery that skin grafts, especially about the face, frequently do not develop a pleasing color in comparison with the surrounding skin They may be lighter or darker, and the underlying mechanism is a subject of much controversy It is possible that there is no loss or gain in pigment in the grafts, but according to whether the graft is stretched or contracted, the color may be lighter or darker as a result of the distribution of the pigment granules At times, there seems to be a definite tendency in a given patient, regardless of the location, to develop lightness or darkness in his grafts. The donor source is of some importance Postauricular skin will often match quite well, but at times is too red Supraclavicular skin is usually best for small grafts, and skin from the lower anterior chest wall matches best for larger grafts

We know of no completely satisfactory solution to the problem Special cosmetics may completely conceal it in women if they are skillfully blended with the surrounding skin, but leave much to be desired in men and children Prominent and excessively white or red border scars may accentuate the condition and should be excised A good suntan on the whole face will sometimes help blend the graft in with the other skin but at times may make the situation worse

PERMANENT COLOR INJECTION OF GRAFTS AND FLAPS

Miss Gertrude Hance has developed a method of tattooing permanent pigments into grafts or flaps that are too white This often helps appreciably in making them match the surrounding skin Usually, the work is not started until the repair is several months old and has undergone most of its spontaneous color changes, but it may be cautiously started earlier if it is evident that more color will be needed (Figs 317 and 318).

Commercial pigments are used and may be obtained from some of the larger drug houses White is usually barium sulfate yellows and browns are ochers (earthly metallic oxides, red may be an iron oxide or alizarin and black is carbon The pigments may be autoclaved each time or kept as a sterile stock supply They are mixed on a sterile glass slab under daylight and moistened with saline until about the consistency of thick cream For matching a graft to the face skin one starts with small amounts of red yellow and white, adding just a touch of black or brown if necessary An accurate color sense is essential for the work which is often better developed in artists than in physicians and nurses as a class The correct mixture will be only a shade darker than the skin, but it is better to err (if at all) on the side of too light a color, as this can be darkened by subsequent injections

The skin is prepared with soap, water and alcohol Sterile instruments are used, the chief one being the injection or "tattooing" needle This is made by soldering from 2 to 6 small needles in a row on a small bar and attaching the latter to the end of a small artist s paint brush handle The pigment is picked up on the needle points and the needles are inserted obliquely into the skin, the needle pricks being very close together Local anesthesia can be used if necessary After one has had considerable experience one can use a mechanical needle for greater speed in covering large areas but the hand needle is safer for the beginner There is some inflammation and peeling of the skin afterward, lasting from 1 to 2 weeks

The color should be built up gradually, and it may be best to do it in 2 or 3 sittings a few weeks apart It may not be essential



Fig 317 Small split skin grafts on eyelids noticeable because of excessive whiteness (taken from thigh) Color matched to face later (right photo) by injecting permanent pigment into them



Fig 318 Face flap (from chest) noticeable because of excessive whiteness and improved by permanent color injection into it. (Hance, Gertrude and Brown J B Byars L. T and McDowell Frank Color matching of skin grafts and flaps with permanent pigment injection Surg , Gynec. & Obst. 79 624-628)

to color the whole graft uniformly if one brings the color of the edges up to that of the surrounding skin It is particularly important to get enough points of color in the surrounding border scars to break up the visual white line between the grafts and its environs

Solid red can be used for correcting irregular vermilion borders or for extending them and black can be used to cover small eyebrow losses

GROWTH OF HAIR IN GRAFTS

The growth of hair in grafts may mar an otherwise pleasing result It may be prevented at times by choosing a relatively hairless donor area When present, it may be best to destroy the hair follicles individually by electrolysis It may help the electrologist if she is told that the direction of the follicles is apt to be abnormal for the region.

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Final Results

PERSISTENCE OF FUNCTION

Function has been found to persist in large skin grafts which have been in place during long periods of growth (Figs 319 320, 321 322 and 323) Both thick split and full thickness grafts do seem to grow or at least stretch out, with growth of the body surface and to permit normal movement, if they have been successful from the start This has been true in many patients and over areas of the body from the face to the feet

By satisfactory late function of the grafts is meant (1) enough skin for free move ment (2) moderate looseness, (3) ability to withstand the usual trauma of getting around, (4) the development of normal sensation Full normal sensation usually develops in free skin grafts and is influenced

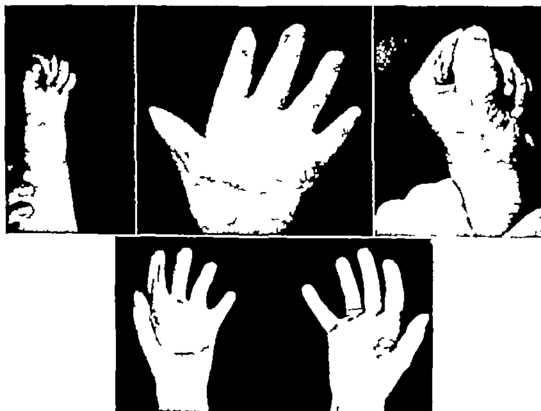


FIG 319 (*Top left*) Complete flexion deformity in boy 3 years of age (*Top center and right*) Full function obtained by careful opening of the hand and covering with a single full thickness graft. (*Bottom*) Shown 13 years later The graft has definitely enlarged and is satisfactory to the boy in every way (Ann Surg 107 963)

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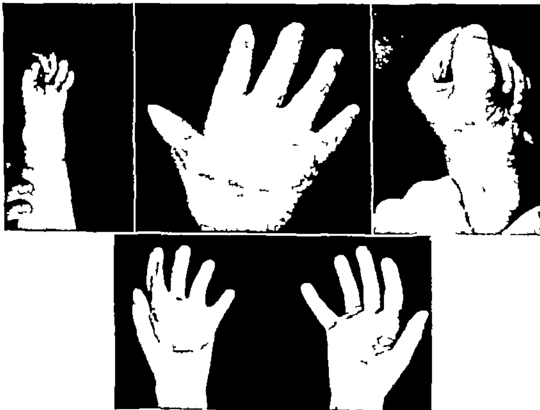


FIG. 319 (*Top left*) Complete flexion deformity in boy 3 years of age (*Top center and right*) Full function obtained by careful opening of the hand and covering with a single full thickness graft. (*Bottom*) Shown 13 years later The graft has definitely enlarged and is satisfactory to the boy in every way (Ann Surg 107 963)



FIG 320 (*Left*) Contracted axilla opened because of a dirty sinus, deep in the scar (*Right*) Total restoration of function having persisted through a 12-year growing period (Ann Surg 115 672)

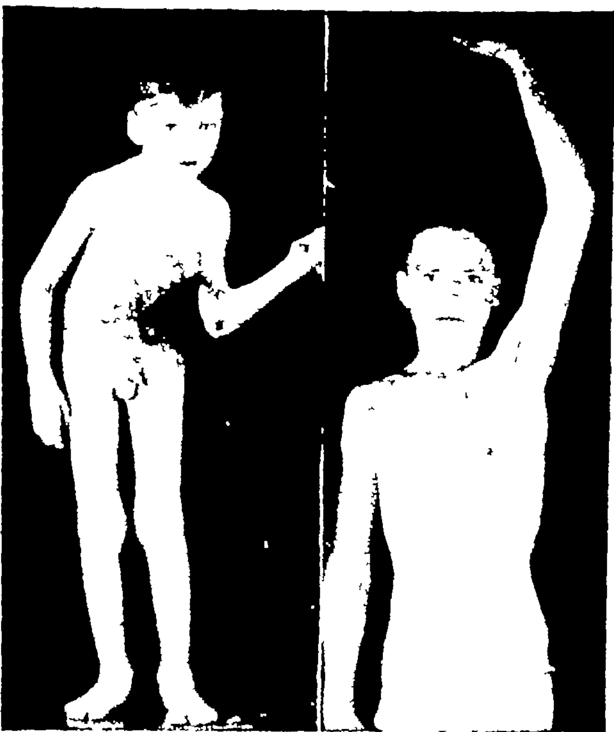


FIG. 321. Contracted axilla and elbow with deep raw surface almost to peritoneum Repaired with thick split grafts (after using homografts to tide patient over critical period) and shown after 9-year growing period Same patient as Figure 235 (Surg, Gynec & Obst 72 848)

by the amount of deep scar that is left and, of course, is dependent on the presence of sensory nerves in the area

GROWTH OF GRAFTS

Metaplasia of grafts (and flaps also) does not take place and, therefore, a really normal sole of the foot, for instance, cannot be restored This area is specialized to the point of being an organ, the skin and the subcutaneous tissues are different from birth, and the peculiar bearing qualities are not developmental A graft or flap on a sole may make calluses (or even annoying warts) but it will not metaplase into the true skin or subcutaneous tissue of that area. Skin grafts transplanted to normal mucous membrane surfaces such as the mouth, the larynx and the eye socket show no evidence of a change to mucous membrane (Figs. 324 and 325) The skin simply persists as such and even raises hair in these areas if there are any functioning follicles in the graft

The results of grafting vary in different regions and with the type of lesion A graft put on a soft base with a good blood supply





FIG 322 One of the most difficult contractures with heavy distorting scar encasing entire arm and wrist. Five split grafts were required, but complete function of the skin grafts persists after a 5-year period of growth (Surg, Gynec. & Obst. 72 848)



FIG 323 Complete function from two split graft operations though patient came in for amputation. Recorded a second time after 9-year growth period with satisfactory enlargement of grafts and good persistence of function Same picture as in Figure 152 (Surg., Gynec. & Obst 72 848)



FIG 320 (*Left*) Contracted axilla opened because of a dirty sinus, deep in the scar. (*Right*) Total restoration of function having persisted through a 12-year growing period (Ann Surg 115 672)

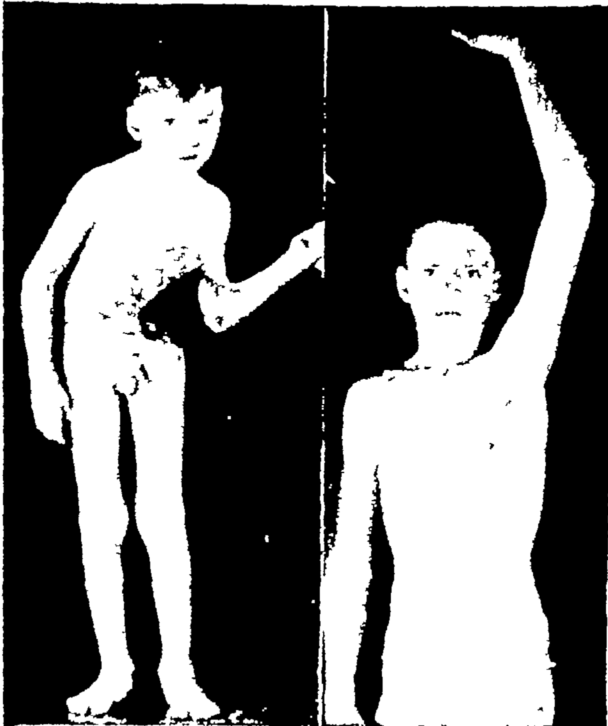


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Fig 323 Complete function from two split-graft operations, though patient came in for amputation Recorded a second time after 9 year growth period with satisfactory enlargement of grafts and good persistence of function. Same picture as in Figure 152 (Surg Gynec. & Obst 72 848)



FIG. 320. (*Left*) Contracted axilla opened because of a dirty sinus, deep in the scar (*Right*) Total restoration of function having persisted through a 12-year growing period (Ann. Surg 115 672)

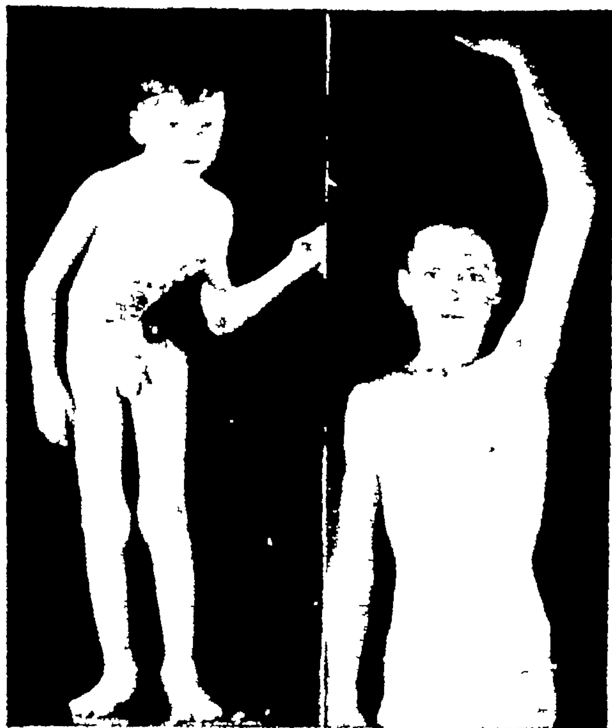


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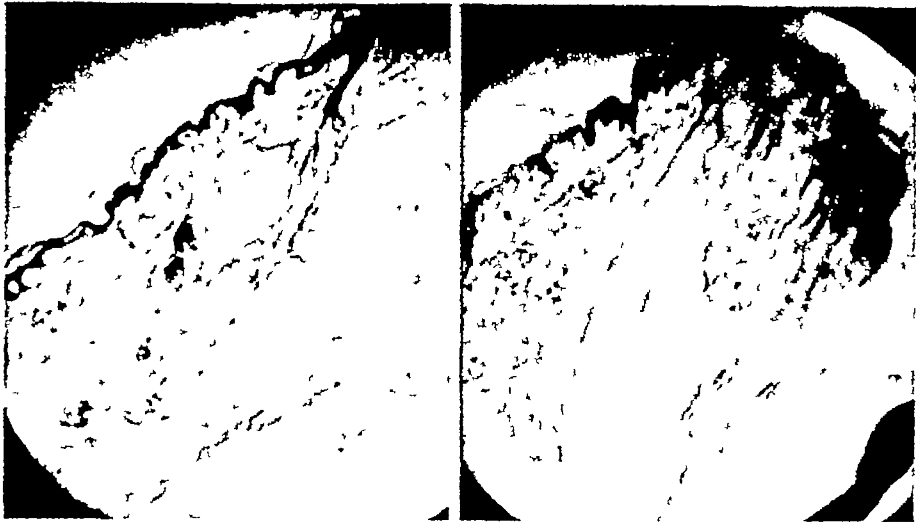


FIG 324 Failure of metaplasia of skin grafts (*Left*) Biopsy after 1 year—from graft in orbit. Graft is still skin, grossly and microscopically (*Right*) Biopsy after 5 years—from inside larynx Graft is still skin, with hair growing from it (Ann Surg 115:1170)

can be expected to be more certain than if put over the shin or the ankle where there is little deep pad to help absorb shocks and trauma A frequent cause of loss of grafts applied to long-standing fibrosed ulcers is failure to remove the scar down to soft bleeding tissue, and this may contribute to recurrent late ulceration even if the graft takes

Although grafts and and flaps are not being compared, a successful graft may be more apt to continue satisfactorily throughout a growing period than a pedicle flap, because flaps have a tendency to hump up and become heavy from fat rather than to spread out

Cosmetic results with free skin grafts may not be as good as the functional results described What would be a good functional result on a leg or an axilla might be a very poor one on the face, because of roughness and pigmentation However, the same general rule applies for a late desirable cosmetic result as for function if the



FIG 325 Routine lack of metaplasia in skin grafts The area of warty leukoplakia on the tongue was excised and resurfaced with split-skin graft from the thigh, in a Negro (*Right*) Graft remains black and looks exactly like original skin 5 years later




FIG. 326 Skin burnt off the entire face with resultant encasement in contracted rigid scar The patient had not closed her eyes even in sleep for more than 20 years Result obtained by removal of scar and replacement with skin grafts mostly full thickness. The increase in the amount of skin in the face permits all normal movements of expression, as well as easy closure of the eyes The eyebrows were made with island flaps from the scalp (Same patient as in Fig 79)

graft has been satisfactory soon after operation it probably will persist in this satisfactory condition (Figs 326 and 327)

Any transplant on the face or the neck should be avoided when at all possible to do so by using rotated local flaps repeated excision of the scar in stages or by any other procedure However, this should not be carried out to the point of creating deforming tension on the features Exposed grafts may not be perfect in appearance, but the situation in burns over wide areas of the face and the neck is different from that involved in the removal of melanomas hemangiomas etc. in that deep scarring may prevent satisfactory shifting of local tissue

REHABILITATION OF PATIENTS

The final criterion of the result is the extent to which the patient is able to resume his normal station in life and carry out his usual activities without embarrassment in regard to his appearance, or limitation in his motions This optimum goal seems to be a high one, but can be attained surprisingly often by sufficient persistence on the part of the surgeon and others caring for the patient. The mental readjustment during the first few months after completion of the repair may be the most difficult part of all Sympathy tact and understanding on the part of all at this time may contribute greatly to the ultimately successful result Social workers, occupational therapists and intelligent friends and relatives may help to pave the way

It will be found that the patient s attitude toward his final result will often reflect the co-operation that has existed between him and his surgeon in deciding what to do and

when to do it In this field of surgery it is difficult to get away from this individual doctor-patient relationship The demands of the patient through a long series of operations will not allow it in the first place, the clinical results cannot be good without it in the second place, and there is some intangible feeling of the surgeon for his work that does not allow widespread mass production of the important details of repair This might be called individual artistry, but the results are so far short of artistry that the surgeon does not like to be stigmatized with it or thought of as being able to make things perfect He aims at function first, and with this goes a plan and effort to restore contour and smoothness to as near normal as possible (Fig 328).



FIG 327. Burn contracture with dislocation of neck (atlas upon axis). Repaired in 3 grafting operations, and reduction of dislocation (Neck dislocation accompanied the accident of the burn, it was not caused by contracture)

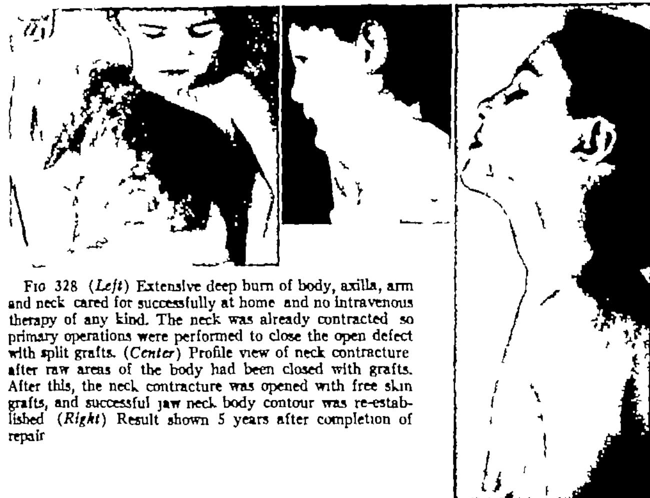


FIG 328 (*Left*) Extensive deep burn of body, axilla, arm and neck cared for successfully at home and no intravenous therapy of any kind. The neck was already contracted so primary operations were performed to close the open defect with split grafts. (*Center*) Profile view of neck contracture after raw areas of the body had been closed with grafts. After this, the neck contracture was opened with free skin grafts, and successful jaw neck body contour was re-established (*Right*) Result shown 5 years after completion of repair

Perhaps most important of all is that the patient retain his will to do and not consider himself as being permanently and inescapably handicapped One heroic example of this was a farmer who was the worst burned patient that we have yet seen and had sufficient disability insurance to care for himself indefinitely Upon completion of his repair he relinquished his claims climbed back up on the same tractor upon which he was burned and resumed tilling his fields

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